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Anadromous Fisheries Research Program, Virginia - Annual Report 1980

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PREFACE

This presentation is the first annual report for P. L. 89-304, AFC 10 project "Anadromous Fisheries Research, Virginia," for the period 1 October, 1979 to 30 September, 1980. The fishes of concern were the alewife (Alosa pseudoharengus), American shad (A. sapidissima), and the blueback herring (A. aestivalis).

The following jobs were contracted by the Virginia Institute of Marine Science.

Job 1. Catch and Effort Statistics of the Virginia Anadromous Fisheries

Objectives

1. Estimate fishing effort, landings, and catch per unit of effort (CPUE) of adult striped bass and Alosa fishes in Virginia during the 1980 fisheries.
2. Determine the present status of the stocks relative to former years by comparison of landings and CPUE.

Job 2. Population Dynamics of the Virginia Alosa Fisheries

Objectives

1. Estimate current vital statistics (age and size frequencies, species composition, mortality rates, etc).
2. Contrast current vital statistics to the existing Virginia data base for the Alosa fisheries.

Job 3. Annual Index of Juvenile Alosa Abundance

Objectives

1. Determine an index of abundance for juvenile alewives, blueback herring, and American shad.
2. Study the growth and relative abundance of juveniles over time.
3. Study changes in nursery zone boundaries and the distribution of juveniles within zones over time.

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Potomac River catch data were supplied by Commissioner Robert M. Norris and his staff of the Potomac River Fisheries Commission.

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Job 1. Catch-Effort Statistics, Inshore Alosa Fishery

SUMMARY

1. Stake gill nets in the James River yielded an estimated 0.4 million kg of American shad in 1980.

2. The catch-per-unit-of-effort (CPUE) for stake gill nets in the James River increased from 7.6 kg/m in 1979 to 9.6 kg/m in 1980.

3. Pound nets in the York River landed an estimated 8,720 kg of American shad and 220,346 kg of river herring in 1980.

4. Stake gill nets in the York River landed an estimated 261,731 kg of American shad.

5. Pound nets in the Rappahannock River landed an estimated 1,652 kg of American shad and 218,637 kg of river herring in 1980.

6. Stake gill nets in the Rappahannock River caught an estimated 10,197 kg of American shad, a decrease of 57% compared to 1979.

7. Pound nets in the Potomac River landed 989 kg of American shad and 283,983 kg of river herring in 1980, a decrease of 44% for American shad and 37% decrease in landings of river herring compared to 1979.

8. Gill nets in the Potomac River (stake, anchor and drift) yielded 6,532 kg of American shad in 1980, a decrease of 37% compared to 1979.

INTRODUCTION

Stock assessment consists essentially of the collection and analysis of basic data such as catch, effort and development of an index (relative or absolute) of abundance of the fish stock under consideration (Gulland 1978). Estimates of total landings by gear type may be obtained from the product of catch-per-unit-of-effort (CPUE) and the total units of gear fished. Specific values of effort by gear type and CPUE in any particular year are not themselves of exceptional significance but rather it is the trend in the data from year to year that is important (Gulland 1978).

The CPUE and the estimated landings may be used as a relative indicator (index) of stock abundance by a simple comparison with such estimates in prior years, provided there are not large annual fluctuations in availability of the fish and the total units of gear fished remains relatively constant (Rounsefell 1975).

A unit of effort can be expressed as whole units, such as pound nets or haul seine, or as a part of the whole unit such as catch per linear meter of gill net. Recently, Crochet et al. (1976), Klauda et al. (1976), and Jones et al. (1976) expressed CPUE as catch per million ft of net per hr, catch per million yards of net per hr and catch per ft of net per hr, respectively. All authors used catch and/or CPUE as an estimate of relative abundance.

MATERIALS AND METHODS

The 1980 catch estimates of adult Alosa were computed by the method of Hoagman and Kriete (1975). Pound net catch estimates were determined by multiplying the CPUE (kg/net/half-month) of the index nets

by the number of nets actively fishing (weighted by net size) in each section of the river. Index nets are those for which daily records were kept by cooperating fishermen. Effort was determined by semi-monthly aerial counts of active pound nets (Table 1.1 and Fig. 1.1). Yearly pound net CPUE was determined by dividing total landings by the average number of nets fished.

Stake gill net catch estimates were determined by multiplying the CPUE (kg/m of net/half-month) of index nets by meters of stake gill netting in 5-nautical mile sections of the river (Hoagman and Kriete 1975). Effort was determined by a count of stake gill nets during the peak of the American shad fishing season (Table 1.2). Yearly stake gill net CPUE was determined by dividing total landings by total netting fished for shad.

Potomac River catch and effort data were supplied by the Potomac River Fisheries Commission.

RESULTS AND DISCUSSION

The 1980 fishing season for river herring and American shad began during the latter half of February for many Virginia fishermen. It was interrupted on March 1 by a massive snow storm and catches did not resume for most fishermen until after March 10. Few of the gill net stands escaped damage during the storm. Installation of many pound net stands was delayed until late March or April. In addition, there is an increasing practice among pound net fishermen to delay installation of nets until the threat of ice damage has passed. Low abundance combined with low market value does not warrant the risk of net loss or the expense of the additional labor to set the nets for river herring and American shad.

Most stake gill net fishermen began to remove their nets by mid-April because of the large number of blue crabs in the nets as well as rapidly rising water temperature. Average ex-vessel prices for American shad increased in 1980 compared to 1979 (.36/lb vs .24/lb). However the price per pound when adjusted by the consumer price index increased less than .04/lb compared to 1979 and slightly more than .06/lb since 1967 (Table 1.3).

The total number of pound nets in 1980 peaked the second half of May at 272 nets, a slight increase compared to 1979 effort (267 nets) (Loesch et al. 1979) and is 82% of the 1967 pound net effort (Loesch and Kriete 1976). The number of gill nets stands set primarily for American shad increased from 374 in 1979 to 381 in 1980 (Loesch et al. 1979) while total meters of gill netting increased 9% during the same period (Table 1.2).

The 1980 estimated landings of American shad and river herring by pound nets declined relative to 1979 in all rivers reporting pound net catches except alewives in the York and Potomac rivers where landings increased (Table 1.4). Estimated landings by stake gill nets in 1980 increased in the James and York rivers but declined in the Rappahannock and Potomac rivers compared to 1979.

Pound net CPUE declined for all Alosa species in all rivers surveyed except alewives in the York and Potomac rivers which exhibited an increase compared to 1979 (Table 1.5). Stake gill net CPUE of American shad increased in the James River relative to 1979 and, except for the CPUE of males in the Rappahannock River, declined in the York and Rappahannock rivers.

James River

No pound nets were set in the James River during January through June (Table 1.1). However records of fyke net landings in the James River showed a decrease in river herring landings from 10,770 kg in 1979 (Loesch et al. 1979) to 7,640 kg in 1980. Peak landings of alewives and blueback herring occurred during the first half of April and the first half of May, respectively (Table 1.6).

Stake gill nets in the James River caught an estimated 0.4 million kg of American shad during the 1980 spring fishing season (Table 1.7), an increase of 0.1 million kg compared to 1979 (Table 1.4). Peak landings of males occurred during the second half of March while landings of females peaked during the first half of April. By contrast peak landings in 1979 for both sexes occurred in the second half of March (Loesch et al. 1979). Although yearly CPUE in the James River by gill nets for both sexes of American shad increased in 1980 compared to 1979, it was lower than the CPUE observed in 1975, 1976, and 1978 in that system (Table 1.5).

York River

Pound nets in the York River caught an estimated 8,700 kg of American shad and 220,000 kg of river herring in the 1980 spring fishing season (Table 1.8). This represented a 45% decrease in landings of American shad and an increase of 3,000 kg of river herring compared to 1979 (Table 1.4). Females constituted 74% of the American shad landed by pound nets in 1980. By contrast female American shad contributed 44% and 27% in 1978 and 1977, respectively, which was a reversal of the sex ratios observed in 1979 and

1980 (Table 1.4). Alewife landings of 43,400 kg represented 20% of river herring landings, and was a 94% increase in landings compared to 1979 (Table 1.4).

The CPUE for American shad (male and female combined) by pound nets continued to decline, dropping from 2,485 kg in 1978 and 1,310 kg in 1979 to 727 kg in 1980 (Table 1.5). During the same period the CPUE for river herring continued to increase rising from 12,665 kg in 1978 to 18,362 kg in 1980; the modest decline in the 1980 CPUE for blueback herring was offset by an increase in CPUE for alewife.

Peak landings of American shad as well as river herring in pound nets occurred during the first half of May (Table 1.8). The bulk of the fish landed were "down run" or fish that had already spawned and were proceeding downriver toward the ocean.

Stake gill net effort increased in 1980 relative to 1979, reversing a declining trend which began in 1975 (Table 1.5). Estimated landings also increased from 209,500 kg to 271,700 kg during the same period, with females contributing 98% of the increase (Table 1.4). Peak landings in 1980 for both sexes occurred during the second half of March (Table 1.9).

Although American shad landings in 1980 increased relative to 1979 the 1980 CPUE declined due to an increase in effort that far exceeded the modest increase in landings (Table 1.5). This situation exemplifies a fallacy of attempting to determine the status of fish stocks by landings alone.

Rappahannock River

Pound nets in the Rappahannock River yielded an estimated 1,700 kg of American shad and 218,600 kg of river herring during the 1980 spring fishing season (Table 1.10), a 54% decline for all species relative to 1979 (Table 1.4). Much of this decline may be attributed to the paucity of data on landings from nets below mile 30; these nets traditionally land the bulk of the river herring on the Rappahannock River. Installation of index nets was delayed because of ice during early March. In addition, river herring landed during May in 1980 were mixed with other species and sold as scrap to a reduction plant.

The CPUE for pound nets in the Rappahannock River decreased in 1980 relative to 1979, from 97 kg to 51 kg for American shad and from 12,963 kg to 6,833 kg for river herring (Table 1.5). This is the lowest CPUE reported for American shad from pound nets since 1975 and may be in part due to the reasons noted above.

Stake gill nets landed an estimated 10,197 kg of American shad in 1980, a 57% decrease compared to 1979 (Table 1.5). Peak landings of male American shad occurred during the second half of March and the first half of April for females (Table 1.11).

Effort by stake gill netters for American shad continued to decline in 1980 with only 29% of all gill net effort in the Rappahannock River set primarily for shad (Table 1.2). Effort by gill netters has been redirected toward striped bass which are not only more abundant but command a higher ex-vessel price than does American shad.

The CPUE for American shad by stake gill nets continued the decline begun in 1979, declining from 1.8 kg to 1.2 kg (Table 1.5).

Potomac River

Pound nets in the Potomac River landed 1,255 kg of American shad in 1980 with only 989 kg landed during the spring fishing season, i.e., March thru June (Table 1.12). Likewise, only 91% (283,983 kg) of the river herring caught by pound nets during the spring fishing season for river herring and American shad in the Potomac River. The 1980 peak landings for American shad and river herring occurred during May.

The 1980 CPUE data for the Potomac River were based on data from March through June in order that the data were comparable with previous years. The CPUE for American shad by pound nets continued to decline, decreasing 39% from 33 kg in 1979 to 20 kg in 1980 (Table 1.5). Similarly the CPUE for river herring declined 32% from 8,157 kg in 1979 to 5,569 kg in 1980.

Gill nets (anchor and stake combined) in the Potomac River landed 2,866 kg of American shad in 1980, a decrease of 4,972 kg compared to 1979 (Loesch et al. 1979). As in the Rappahannock River, stocks of shad are low and effort by gill netters has been redirected to striped bass which are more abundant and command a higher ex-vessel price; thus, reduced effort contributed to the decline in landings. By contrast landings of American shad by drift gill net increased 43% compared to 1979 (Table 1.12).

Data are not available from the Potomac River Fisheries Commission to derive CPUE for American shad.

Catch-Effort Evaluation

Stocks of Alosa fishes in Virginia have been declining since the late 1960's (Loesch and Kriete 1976, Loesch et al. 1979). However, data from individual rivers do not consistently reflect this continuing decline.

Estimated landings of American shad by pound nets in the York River declined for two years following an increase in 1978 relative to 1977 (Table 1.4). Landings of American shad in the Rappahannock and Potomac rivers continued declining, a trend begun in 1977. Estimated landings of river herring in the York River, on the other hand, have consistently increased since 1977, paralleling an increase in effort in that river. Landings of river herring in the Rappahannock River continued to decline following an increase from 1977 to 1978.

Yearly CPUE of American shad by pound nets declined in all rivers in 1980 relative to 1979 (Table 1.5). Pound nets in the York River continued to have the highest CPUE for river herring in 1980, increasing yearly since 1977.

The 1980 estimated landings of American shad by stake gill nets were the highest in the York River and second highest in the James since 1977 (Table 1.4). Estimated landings of American shad continued to decline in the Rappahannock and Potomac rivers, the Potomac since 1977 and the Rappahannock since 1978.

The CPUE of American shad by stake gill nets has oscillated in the James River since 1975 from a high of 27 kg in 1976 to a low of 7.3 kg in 1977 (Table 1.5). The CPUE in the York River increased steadily from 1976 to 1979 but declined slightly in 1980. The Rappahannock River CPUE followed a similar pattern until 1978 and then declined through 1980. The Potomac River Fisheries Commission no longer reports stake and anchor gill net catches separately, therefore no CPUE was determined for that river.

Landings and CPUE can be used as an indicator of relative stock abundance; however, both statistics must be regarded with caution. Subtle changes may occur in the fisheries which, unless otherwise noted,

can produce erroneous estimates of landings and CPUE. A case in point is the change in pound net effort. Because of diminishing numbers of American shad, and fluctuating prices coupled with increased net costs, pound net stands set primarily to capture American shad have been discontinued. Pound net stands are now either set for summer species, such as weakfish (Cynoscion regalis), croaker (Micropogon undulatus) and spot (Leiostomus xanthurus), or scrap fish which are used for crab bait and fish meal (personal communication via J. Owens). These nets are set after the danger from ice damage has passed and are set in water depths (25-40 ft) considered by many fishermen to be too deep for productive stands for American shad.

Similarly, changes in the stake gill net fishery have been noted in the Rappahannock and Potomac rivers. Prior to 1977 all stake gill nets were assumed to have been set for American shad. In 1977 all of the nets above mile 35 and 40% of the nets below mile 35 were large-mesh nets set primarily to capture striped bass (Morone saxatilis) (Loesch et al. 1977).

We would have been unaware of these changes, which would have biased the estimates of landings and CPUE, had it not been for the cooperating fishermen's daily records.

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Table 1.1. Number of active pound net stands in Chesapeake Bay and its Virginia tributaries during January-June, 1980.

	Area	Jan 16	Feb 27	Mar 10	Mar 25	April 10	May 2	May 23	June 10	June 25
A	James R.									
B	Back R.				1		1	1		2
C	Poquoson R.									
D	York R.			1	2	14	18	20	16	13
E	Mobjack Bay				1	5	6	6	6	6
F	Piankatank R.				2	3	3	3	3	3
G	Rappahannock R.		5	6	26	41	46	43	44	44
H	Great Wicomico R.	1				3	4	4	7	7
I	Potomac R.			1	12	30	70	86	79	79
J	Cape Henry to Fort Wool			1	1	3	5	6	5	6
K	Old Point to Tue Marsh Point			3	5	7	10	14	11	11
L	York Spit					1	1	3	6	6
M	New Point to Stingray Point			1	3	9	18	24	25	24
N	Windmill Point to Smith Point	1	2	1	7	16	31	43	33	37
	Eastern Shore									
O	Above Hungar Creek									
P	Below Hungar Creek	5	3	1	2	6	16	19	23	27
	Total	7	10	15	62	138	229	272	258	265

Table 1.2. Number of stake gill net stands fished in Virginia rivers 1978-1980 (A) and linear meters of gill netting fished primarily for American shad per five mile block (B) in 1980. Figures in parentheses represent the total meters of gill netting in the York and Rappahannock rivers.

A.

River	Number of Gill Net Stands 1978	1979	1980
James	181	168	179
York	118	117	147
Rappahannock	121	155	122

B.

River	Mile	Number of Stands	Number of Sections	Average Length/Section	Meters of Net	
James	05-10	38	913	9		8,217
	10-15	9	128	9		1,152
	15-20	94*	1,500	15		22,500
	20-25	21	319	15		4,785
	25-60	17*	339	15		5,085
		Total 179	3,199			41,739
York	05-10	2	27	10		270
	10-15	36*	657	10		6,570
	15-20	38	618	10		6,180
	20-25	29*	512	7	(3,584)	3,010
	25-29	42*	665	7	(4,655)	3,910
		Total 147	2,479		(21,259)	19,940
Rappahannock	15-20	2	26	17	(442)	234
	20-25	6*	72	17	(1,224)	649
	25-30	25	493	17	(8,381)	4,442
	30-35	22	381	17	(6,477)	3,433
	35-70	67*	1,088	13	(14,144)	
		Total 122	2,060		(30,668)	8,758

*Includes anchor gill net converted to stands.

Table 1.3. Dock-side value and adjusted value of American shad landings in Virginia for the years 1967-1980. Pounds and value in thousands.

Year	Pounds	Value	Consumer Price Index	Adjusted Value	Adjusted Price/lb. (¢)
1967	2138	181	1	181.0	8.46
1968	2550	161	1.04	154.8	6.07
1969	2248	166	1.10	150.9	6.71
1970	4112	315	1.16	271.6	6.60
1971	1520	135	1.21	111.6	7.34
1972	2057	225	1.25	180.0	8.75
1973	2436	366	1.33	275.2	11.30
1974	1569	230	1.48	155.4	9.90
1975	1136	308	1.61	191.3	16.84
1976	896	284	1.70	167.0	18.64
1977	1468	498	1.81	275.1	18.74
1978	1234	211	2.03	103.9	8.42
1979	994	235	2.17	108.3	10.89
1980(a)	973	353	2.47	142.9	14.68

(a) January-July 1980.

Table 1.4. Yearly landings in kg of American shad by pound nets and stake gill nets and river herring by pound nets. Landings for the James, York and Rappahannock rivers are estimations. Landings for the Potomac River are reported by the Potomac River Fisheries Commission.

	Stake Gill Net		Pound Net			
	American Shad		American shad		River Herring	
	♀	♂	♀	♂	Alewife	Blueback
James						
1977	186,495	11,612	[	(a)		]
1978	574,935	116,348				
1979	263,203	17,328				
1980	343,026	59,003				
York						
1977	137,748	3,376	3,217	8,894	10,298	87,966
1978	174,780	31,666	13,141	16,676	16,021	135,954
1979	186,074	23,460	10,224	5,492	22,256	195,150
1980	246,719	25,012	6,453	2,267	43,391	176,955
Rappahannock						
1977	22,053	2,298	1,268	2,949	84,688	209,163
1978	45,870	10,909	1,871	2,096	130,804	381,734
1979	21,619	2,199	1,562	2,046	56,016	423,633
1980	8,831	1,366	1,038	614	23,283	195,354
Potomac (stake, anchor and drift gill net combined)						
1977	29,708	2,704	2,458	3,775	34,671	179,961
1978	20,544	2,858	1,674	1,853	48,942	610,469
1979	9,492	900	649	1,134	11,516	437,152
1980(b)	5,058	1,474	342	647	34,006	249,977

(a) Data not available.

(b) March through June data only.

Table 1.5. Yearly catch-per-unit-of-effort for American shad and river herring 1975-1980 in kg by species for stake gill net and pound net. Stake gill net effort in meters. Pound net effort in number of nets.

		Stake Gill Net			Pound Net				
			American shad			American shad		River Herring	
	Year	Effort	♂	♀	Effort	♂	♀	Alewife	Blueback
James River	1975	25,832	2.7	8.8	[				]
	1976	20,464	1.9	25.1					
	1977	26,884	0.4	6.9			(a)		
	1978	28,134	4.1	20.4					
	1979	37,207	0.5	7.1					
	1980	41,739	1.4	8.2					]
York River	1975	22,106	0.5	4.5	[				
	1976	21,424	0.3	3.0			(a)		]
	1977	19,326	0.2	7.1	10	889	322	1,030	8,797
	1978	15,954	2.0	10.9	12	1,390	1,095	1,335	11,330
	1979	13,968	1.7	13.3	12	458	852	1,855	16,262
	1980	19,940	1.3	12.4	12	189	538	3,616	14,746
Rappahannock River	1975	28,973	0.1	0.8	30	42	60	2,408	5,732
	1976	32,517	0.1	0.5	25	33	55	1,754	2,716
	1977	13,595	0.2	1.6	45	65	28	1,882	4,648
	1978	13,681	0.8	3.4	42	50	45	3,114	9,089
	1979	13,497	0.2	1.6	37	55	42	1,514	11,449
	1980	8,758	0.2	1.0	32	19	32	728	6,105
Potomac River	1975	76,553	0.1	0.5	23	149	43	16,625	89,071
	1976	78,858	<0.1	0.3	32	208	83	4,430	13,502
	1977	75,017	<0.1	0.3	51	74	48	680	3,529
	1978	56,839	<0.1	0.2	45	41	37	1,088	13,566
	1979	[			55	21	12	209	7,948
	1980(b)	(a)]			51	13	7	667	4,902

(a) Data not available.

(b) March through June data only.

Table 1.6. Estimated catch in kg of American shad and river herring by fyke nets in the James River 1980 by half-month intervals.

Half-Month Period	Number Nets	American Shad				River Herring						
		Female		Male				Alewife		Blueback		
		Index	Estimated Total	Index	Estimated Total	Index	Estimated Total	Percent	Estimated Total	Percent	Estimated Total	Number of Index of Nets
March 2nd	13	(a)		(a)		31.4	408	76	310	24	98	9
April 1st	19	2.2	42	1.5	29	73.5	1,397	60	838	40	559	13
April 2nd	23	1.8	41	1.3	30	51.6	1,187	12	142	88	1,045	16
May 1st	23	5.6	129	1.3	30	130.9	3,011	2	60	98	2,951	16
May 2nd	23	2.6	60	0.9	21	69.6	1,601	1	16	99	1,585	16
June 1st	13	(a)		(a)		2.8	36			100	36	9
Total			272		110				1,366		6,274	
				382			7,640					

(a) None reported by index fishermen.

Table 1.7. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the James River 1980 by half-month intervals and by sex. Effort from Table 1.2. Index in kg/m of net.

Half-Month Period	River Mile	American Shad Male Index	Male Estimated Catch	American Shad Female Index	Female Estimated Catch	Total Estimated Catch
March 1st	05-10	.3646	2,996	.6191	5,087	8,083
	10-15		420		713	1,133
	15-20		5,132		6,793	11,925
	20-25	.2281	1,091	.3019	1,445	2,536
	25-60		1,160		1,535	2,695
	Total		10,799		15,573	26,372
March 2nd	05-10	.5680	4,667	3.0958	25,438	30,105
	10-15		654		3,566	4,220
	15-20		15,386		51,536	66,922
	20-25	.6838	3,272	2.2905	10,960	14,232
	25-60		3,477		11,647	15,124
	Total		27,456		103,147	130,603
April 1st	05-10	.9028	7,418	5.4844	45,065	52,483
	10-15		1,040		6,318	7,358
	15-20		6,764		77,130	83,894
	20-25	.3006	1,438	3.4280	16,403	17,841
	25-60		1,529		17,431	18,960
	Total		18,189		162,347	180,536
April 2nd	05-10	.0514	422	2.1206	17,425	17,847
	10-15		59		2,443	2,502
	15-20		1,445		29,257	30,702
	20-25	.0642	307	1.3003	6,222	6,529
	25-60		326		6,612	6,938
	Total		2,559		61,959	64,518
Total by Sex			59,003		343,026	
Grand Total						402,029

Table 1.3. Estimated catch in kg of American shad and river herring by pound nets in the York River 1980 by half-month intervals.

Half-Month Period	Number Nets	American Shad				River Herring						Number of Index Nets
		Female		Male				Alewife		Blueback		
		Index	Estimated Total	Index	Estimated Total	Index	Estimated Total	Percent	Estimated Total	Percent	Estimated Total	
March 2nd	2	3.8	8	2.5	5	26.0	52	27	14	73	38	4
April 1st	14	68.8	963	18.0	252	1,531.0	21,434	29	6,216	71	15,218	4
April 2nd[a]	16	113.6	1,818	48.4	774	4,232.1	67,714	30	20,314	70	47,400	8
May 1st[a]	18	153.2	2,758	51.9	934	5,753.9	103,570	16	16,571	84	86,999	9
May 2nd[a]	20	45.3	906	15.1	302	1,378.8	27,576	1	276	99	27,300	9
Total			6,453		2,267				43,391		176,955	
				8,720			220,346					

([a]) American shad indices include estimated sex ratios for landings not reported by sex.

Table 1.9. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the York River 1980 by half-month intervals. Effort from Table 1.2. Index in kg/m of net.

Half-Month Period	River Mile	American Shad: Male Index	American Shad: Male Estimated Catch	American Shad: Female Index	American Shad: Female Estimated Catch	Total Estimated Catch
February 2nd	05-10		60		168	228
	10-15	.2209	1,451	.6219	4,086	5,537
	15-20		1,365		3,843	5,208
	20-25	.0642	193	.2941	885	1,078
	25-29		251		1,150	1,401
	Total		3,320		10,132	13,452
March 1st	05-10		87		331	418
	10-15	.3218	2,114	1.2264	8,057	10,171
	15-20		1,989		7,579	9,568
	20-25	.3121	939	.9595	2,888	3,827
	25-29		1,220		3,752	4,972
	Total		6,349		22,607	28,956
March 2nd	05-10		156		1,474	1,630
	10-15	.5770	3,791	5.4592	35,867	39,658
	15-20		3,566		33,738	37,304
	20-25	.4406	1,326	4.9425	14,877	16,203
	25-29		1,723		19,325	21,048
	Total		10,562		105,281	115,843
April 1st	05-10		46		947	993
	10-15	.1686	1,108	3.5069	23,040	24,148
	15-20		1,042		21,673	22,715
	20-25	.2399	722	4.7434	14,278	15,000
	25-29		938		18,547	19,485
	Total		3,856		78,485	82,341
April 2nd	05-10		14		237	251
	10-15	.0504	331	.8769	5,761	6,092
	15-20		311		5,419	5,730
	20-25	.0388	117	2.7164	8,176	8,293
	25-29		152		10,621	10,773
	Total		925		30,214	31,139
Total by Sex			25,012		246,719	
Grand Total						271,731

Table 1.10. Estimated catch in kg of American shad and river herring by pound nets in the Rappahannock River 1980 by half-month intervals.

Half-Month Period	Mile	Number Nets	American Shad: Female Index	American Shad: Female Estimated Total	American Shad: Male Index	American Shad: Male Estimated Total	River Herring: Index	River Herring: Estimated Total	River Herring: Alewife Percent	River Herring: Alewife Estimated Total	River Herring: Blueback Percent	River Herring: Blueback Estimated Total	Number of Index Nets
February 2nd	0-30	1	[(a)]		[(a)]		(a)						
	31-70	4					6.5	26	100	26			2
March 1st	0-30	3	[(a)]		[(a)]								
	31-70	3					25.3	77	76	58	25	19	5
March 2nd	0-30	12	(a)		(a)		(a)						
	31-70	14	6.3	88	8.8	123	27.0	378	51	193	49	185	12
April 1st	0-30	24	(a)		(a)		(a)						
	31-70	17	8.8	150	4.4	75	566.6	9,632	27	2,601	73	7,031	14
April 2nd	0-30	26	13.0	338	3.3	86	6,902.3	176,860	11	19,455	89	157,405	4
	31-70	18	3.9	70	3.3	59	802.5	14,445	3	433	97	14,012	14
May 1st	0-30	28	13.0	364	3.3	92	(a)						4
	31-70	18	1.1	20	9.5	171	956.6	17,219	3	517	97	16,702	14
May 2nd	0-30	28	(a)		(a)		[(a)]						10
	31-70	15	0.5	8	0.5	8							
Total				1,038		614		218,637		23,283		195,354	
					1,652								

(a) None reported by index fishermen.

Table 1.11. Estimated catch in kg of American shad by stake gill nets in the Rappahannock River 1980 by half-month intervals. Effort from Table 1.2. Index in kg/m of net.

Half-Month Period	River Mile	American Shad: Male Index	American Shad: Male Estimated Catch	American Shad: Female Index	American Shad: Female Estimated Catch	Total Estimated Catch
March 1st	15-20	.0080	2	.0126	3	5
	20-25		5		8	13
	25-30		36		56	92
	30-35		27		43	70
	35-70[a]					
	Total		70		110	180
March 2nd	15-20	.0826	19	.2769	65	84
	20-25		54		180	234
	25-30		367		1,230	1,597
	30-35		284		951	1,235
	35-70[a]					
	Total		724		2,426	3,150
April 1st	15-20	.0417	10	.4300	101	111
	20-25		27		279	306
	25-30		185		1,910	2,095
	30-35		143		1,476	1,619
	35-70[a]					
	Total		365		3,766	4,131
April 2nd	15-20	.0237	6	.2888	68	74
	20-25		15		187	202
	25-30		105		1,283	1,388
	30-35		81		991	1,072
	35-70[a]					
	Total		207		2,529	2,736
Total by Sex			1,366		8,831	10,197

(a) None reported by index fishermen.

Table 1.12. Total catch in kg of Alosa fishes by gill nets (A) and pound nets (B) in the Potomac River 1980.

	American Shad					River Herring				
	Virginia		Maryland			Virginia		Maryland		
	Female	Male	Female	Male	Total	Alewife	Blueback	Alewife	Blueback	Total
A. Anchor and Stake Gill Nets										
January	1				1					
February		1		56	57	17[1]	1[1]	1[1]		19
March	34	19	29	12	94	563[1]	30[1]	119[1]	6	718
April	223	98	2,029	243	2,593	20	487	10	233	750
May	32	13	55	21	121	55	290	2	8	355
June										
July		3			3					
August		4		11	15					
September				8	8					
Total	290	138	2,113	351	2,892	655	808	132	247	1,842
Drift Gill Net										
April	1,568	543			2,111	4	109			113
May	1,087	468			1,555	25	134			159
Total	2,655	1,011			3,666	29	243			272
B. Pound Net										
March						142[1]	8[1]	58[1]	3[1]	211
April	195	100	14	6	315	2,586	62,059	116	2,781	67,542
May	124	434	7	1	566	23,329	122,480	7,542	39,594	192,945
June	2	106			108	231[1]	22,877[1]	2[1]	175[1]	23,285
July						220[1]	21,979[1]			22,199
August				225	225	23[1]	2,290[1]		5[1]	2,318
September						8[1]	2,305[1]			2,313
October	41				41					
Total	362	640	21	232	1,255	26,539	233,998	7,718	42,558	310,813
Total	3,307	1,789	2,134	583		27,223	235,049	7,850	42,805	
Grand Total					7,813					312,927

[1] species ratio estimated

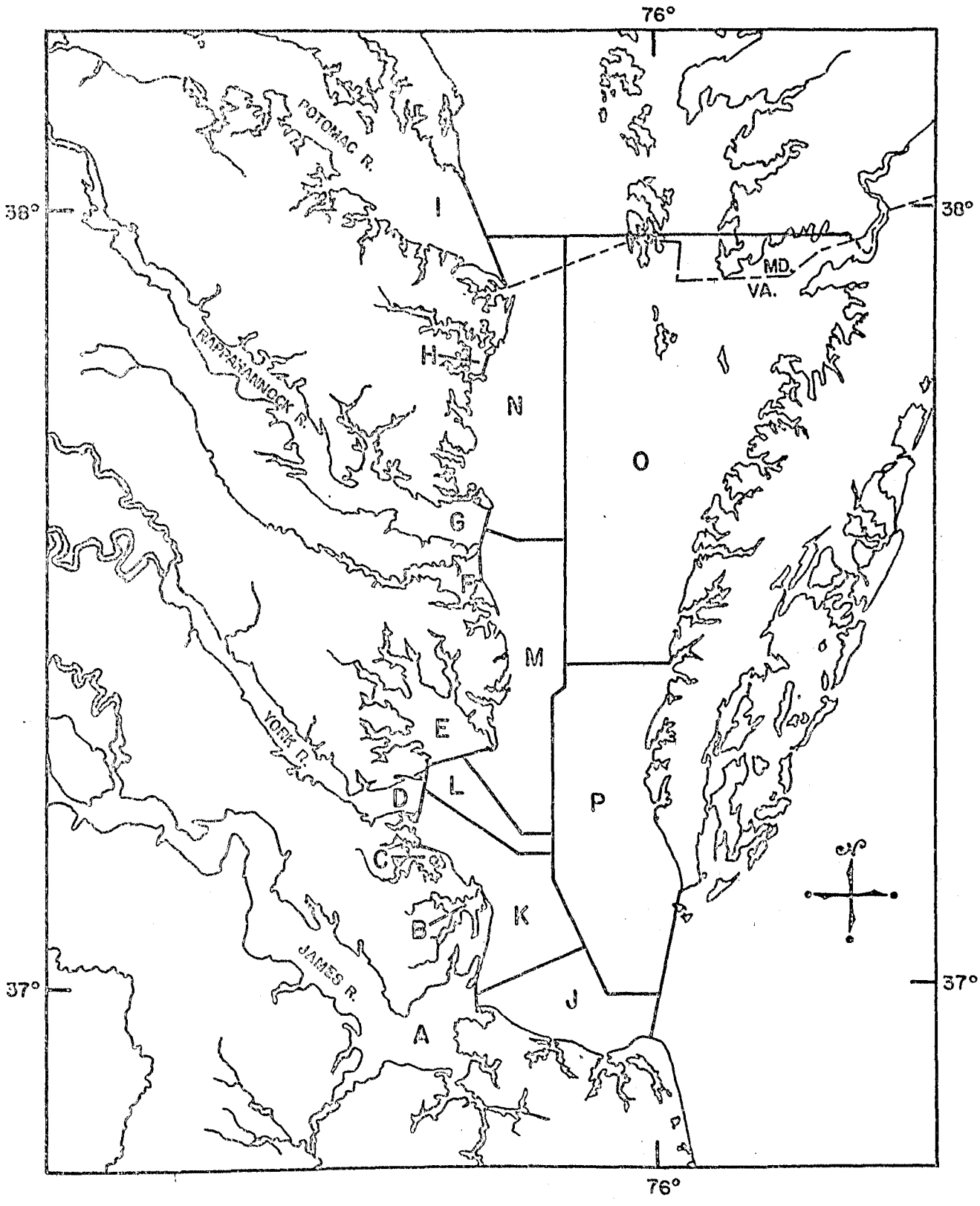

Figure 1.1. Area designations utilized during aerial pound net counts.

Job 2. Population Dynamics of the Virginia Alosa Fishery

SUMMARY

1. The 1980 river herring (alewives and blueback herring) landings in Virginia of 537 metric tons (MT) was 30% less than the 1979 landings (766 MT), and was the lowest catch recorded in the last 15 years. Catch-per-unit-effort data indicated that the decline reflected a reduced availability of blueback herring in 1980, although they still dominated the river herring composition.

2. Age structure, length and weight, and sex ratio determinations were made. The findings were compared with those for previous years, and were used to estimate year-class contributions to total landings for river herring.

3. Prior to the 1972 cohort, total year-class contributions to the alewife fishery in the Potomac River ranged from 251 to 635 MT. Age 4 fish were a substantial proportion of these landings. Few age 4 fish were present in the 1976, 1977, and 1978 catches, and landings greatly decreased. There was a modest increase in the proporton of age 4 biomass in the 1979 and 1980 landings.

4. Preliminary estimates of the instantaneous natural mortality rate (M) and the catchability coefficient (q) were made. The problems encountered in these estimates ($M = 0.51$; $q = 2.1 \times 10^{-4}$), primarily sample size, and the means to enhance the analysis were discussed.

Job 2. Population Dynamics of the Virginia Alosa Fishery

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) continued its annual assessment of the structure of adult Alosa populations in Virginia inshore waters. These data are essential for any consideration of an alosine management plan.

MATERIALS AND METHODS

Methods of sampling Virginia's Alosa commercial fishery were reported by Johnson et al. (1978). The methods remained unchanged in 1980 except that samples were collected monthly (due to monetary constraints) instead of semi-monthly as in 1979.

Sampling of the James, York, and Rappahannock alosine fisheries in 1980 commenced in March; sampling of the Potomac River fishery started in April.

When available, 45 kg of river herring were randomly sampled from commercial pound net or fyke net catches. These nets employ a 50.8 mm stretched mesh in their entrapment section. This mesh size is required by Virginia law (Sec. 28.1-51) for pound nets when taking "food fish" and is assumed to be nonselective for river herring age 3 and older.

Random samples of up to 100 American shad were taken from commercial catches. The fishery primarily employs gill nets with mesh sizes (12.4-14.0 cm) which favor the capture of females, the larger of the sexes. Employment of large mesh nets biases the sex ratio, and results in

overestimates of the parameters of mean length, mean weight, proportion of older fish and the proportion of repeat spawners.

River herring samples were returned to VIMS where they were sorted by species and sex, body length and weight recorded, and scales and otoliths removed from random subsamples. American shad data were collected at the sampling site, except for age and spawning frequency data which were derived from laboratory analysis of scales. Ages of river herring were determined from otoliths and American shad age from scales by the method of Cating (1953), i.e., counting the number of annuli and spawning check marks, and adding a year for the scale edge. Beal (1968) and Marcy (1969) used scales and found the method applicable for river herring. Kornegay (1979) in North Carolina and Lipton (1979) and Travelstead (1980) in Virginia found the use of otoliths applicable for ageing river herring.

Domestic river herring landings data for the years 1966-1972 were obtained from the respective U.S. Fishery Statistical Digests; subsequent data were from the annual summaries of Current Fisheries Statistics, NMFS, Division of Statistics and Market News. Offshore foreign landings data were obtained from the respective ICNAF Statistical Bulletins.

A computer "package program", SPSS (Nie et al. 1975), was used to construct Tables 2.3 through 2.10.

RESULTS AND DISCUSSION

Sampling Effort

During the 1980 spawning season, 557 alewives, 2,354 blueback herring and 583 American shad were sampled (Table 2.1). The number of river herring

collected in 1980, as in 1979 was considerably less than in previous years (Loesch et al. 1977; Johnson et al. 1978). A savings in time, effort, and money was accrued due to the use of otoliths. Very few otoliths were unreadable. In contrast, large samples were needed in past years to obtain a relatively small proportion of usable scales due to their loss or damage in the pound net fishery.

River Herring Landings

The 1980 river herring landings in Virginia of 537 metric tons (MT) was 30% less than the 1979 landings (766 MT), and was the lowest catch recorded in the last 15 years (Table 2.2). Catch-per-unit-of-effort (CPUE) data indicated that the 1980 decline in landings reflected a reduced availability of blueback herring. The findings in Table 1.5 (Job 1) show that alewife landings and CPUE for pooled catch and effort data of the York, Rappahannock, and James rivers increased in 1980. Conversely, blueback herring catch and CPUE declined. In addition to the method in Job 1, a mean CPUE of Potomac River river herring was also calculated by weighting numbers-at-age by the total numbers caught in sampling periods; these findings are in agreement with those of Table 1.5. Alewife CPUE (mean number/net/day) in the Potomac River in 1979 was 11.7 but rose to 37.5 in 1980; however, blueback herring CPUE dropped from 557.4 in 1979 to 130.6 in 1980. Since blueback herring have dominated the Virginia river herring landings in recent years (81% in 1980), their decline greatly affected the total river herring catch in 1980.

The 1980 decline in river herring landings in Virginia continued the general decline that started in 1970, and is attributed to poor recruitment

(Loesch et al. 1977) and heavy exploitation of river herring by the foreign offshore fishery in the late 1960's and early 1970's (Hoagman et al. 1973). River herring recruitment and foreign exploitation were previously discussed in detail (Loesch et al. 1979).

Age Composition

The age frequency of river herring (sexes pooled) by river by species determined from samples of the commercial fisheries catches in 1980 is presented in Tables 2.3-2.10. Mean and modal age data for the years 1977-1980 are summarized in Table 2.11. The mean and modal ages of river herring in 1980 increased relative to 1979 due to a "strong" 1975 year class (relative to other year-class recruitment in the past decade). The most notable features of the 1979 and 1980 river herring age frequencies were the relatively high percentages of ages 3 and 4 (Tables 2.3-2.10). Age 3 river herring were absent or rare in samples from the pound net fisheries in the Rappahannock and Potomac rivers from 1975 to 1978 (Tables 2.12-2.15). Similarly, age 4 was poorly represented from 1976 to 1978. The greater contribution of these younger age classes to the total catch indicated a reversal of the ageing trend in Virginia river herring reported by Johnson et al. (1978). Hoagman and Kriete (1975) reported an exceptionally high density of young-of-the-year (juvenile) blueback herring in 1975. However, that high density of juveniles does not appear to have materialized as exceptionally strong recruitment as evidenced by the decline in blueback herring catch and CPUE in 1980. The data (Tables 2.12-2.15) also indicate that the 1976 alewife year class was also relatively successful. Several successive years of reasonably good recruitment (e.g., 1975 year class) will

be necessary to stabilize the river herring fishery at its present low level, or perhaps show a modest gain in strength.

The American shad fishery is primarily a gill net fishery and catches are biased toward larger and older fish, mostly females, because of net selectivity. Also, males are often discarded at the net when their market price is low. Therefore, data on age structure, sex ratio, and other vital statistics based on gill net samples, are relevant only to fish landed.

American shad age frequency data by river for 1980 are summarized in Table 2.16, and age frequencies for all rivers for the years 1977-1980 are summarized in Table 2.17. A chi square test of independence was highly significant ($P<0.0001$ for both males and females), indicating that age frequency was not independent of years. The significance is due to a shift from an age 5 mode in 1977 to age 6 in 1978 and 1979 and then back to age 5 (males) and ages 5-6 (females) in 1980. Thus, the American shad changes in mean and modal ages tend to parallel the river herring age changes (Table 2.11). Since all three alosine species have overlapping spawning seasons and all are estuarine-dependent during their first-year development, similar year-class success could be expected. The main difference between the American shad and river herring trends is that mean and modal ages of American shad did not decrease in 1979 and increase slightly in 1980 as did these values for river herring. We believe this was due to gill net mesh size changes during the shad season. Logbook data and personal communications with gill net fishermen revealed that when early sparse catches indicated a poor shad season, fishermen used larger

mesh sizes to fish for the also scarce but more valuable striped bass. Thus, age frequency changes cannot be interpreted until gill net catches can be partitioned by mesh sizes, and inferences about the population age structure cannot be made until the selectivity of each gill net size is estimated.

Length and Weight Analysis

Mean fork length and total body weight of river herring in 1980 (Table 2.18), in general, increased relative to the 1979 values (Loesch et al. 1979). This reflected the modest increase in mean and modal ages in 1980. Loesch et al. (1979) reviewed the long-term trends of mean length and weight of Virginia river herring stocks. They concluded that changing age-class structure, due to varying recruitment, and not fishing activities, was responsible for the observed cyclic-like changes in mean length and weight.

The most pertinent use of these data, specifically mean weight-at-age, in conjunction with sex ratio data, was to estimate year-class contributions to total landings (Tables 2.13-2.15).

No American shad samples were obtained from pound nets in 1980. Our only unbiased length and weight data for shad are from 39 males and 48 females taken in Potomac River pound nets in 1977. These data indicated that male shad had a mean fork length and mean weight of 405.8 mm and 837.3 g, and the respective means for females were 422.0 mm and 989.1 g.

Sex Ratio

Chi square analysis of the homogeneity of sex ratios among the river specific samples was highly significant ($P<0.001$) for both alewives and blueback herring (Table 2.19-2.20). The heterogeneity was due to significantly

larger numbers of female alewives in the Potomac River and male blueback herring in the James River. Samples from the commercial catches in the other rivers did not vary significantly from a 1:1 sex ratio ($P>0.10$). Variations in sex ratios can be due to chance (sampling error), changes in age structure, or the location of sampling sites. The latter two considerations were discussed by Loesch et al. (1979).

The sex ratio data were used in conjunction with mean weight-at-age data to estimate year-class contributions to total landings (Tables 2.13-2.15).

Species Composition

Blueback herring constituted 81% of the river herring sampled in 1980 (Table 2.1); this value is unchanged from 1979. Loesch et al. (1979) showed that there has been a significant increase in the proportion of blueback herring relative to alewives since 1974. Thus, as the Virginia river herring stock has declined since the early 1970's, the rate of decline for alewives has been greater than the rate for blueback herring. This trend could be a natural cyclic-like phenomenon. Another conjecture is that impoundment activities in Virginia in the recent past have resulted in a greater loss of spawning grounds for alewives than for blueback herring. Loesch and Lund (1977) reported that alewives and blueback exhibited a spatial separation when spawning, the former species preferring slow flowing water or lentic environments while the latter chose faster flowing sites. Thus, impoundment without a means of upstream passage could result in a great loss of spawning grounds for alewives but a lesser loss

for blueback herring which can spawn in rapid main-stream flow below impoundments. The increase in agrichemical usage, pesticides in the 1960's and 1970's, and herbicides used in conjunction with no-till farming in the 1970's, may also have contributed to the decline in American shad and river herring stocks in the Chesapeake Bay region. Agrichemical contamination could have a greater effect upon alewife spawning success in a minor stream that is tributary to a larger system in which American shad and/or blueback herring spawn. Dilution of contaminants would be greater in a larger system, and contaminant degradation more advanced if entry was via the minor stream.

Cohort Contributions to the River Herring Fishery

The annual and total cohort (year-class) contributions in metric tons to the Potomac and Rappahannock river herring fisheries were estimated (Tables 2.21-2.24). Cohort biomass in the Potomac fishery was determined from monthly estimates of sex ratios, age structure, and mean weight-at-age, and the reported monthly landings. The monthly cohort contributions were summed over the fishing season to obtain the annual biomass harvested. Annual cohort biomass values for the Rappahannock fishery, at this time, have not been weighted by landings in the sampling periods, i.e., the values are derived from seasonal estimates of sex ratio, age structure, and mean weight-at-age, and the reported total harvest.

The strongest contributor of record to the Potomac River alewife fishery (Table 2.21) was the 1966 cohort (635 MT). Other relatively strong contributors were the 1970 and 1971 cohorts (398 and 373 MT). Although more effort (net days) was associated with the catch of the 1966 cohort, CPUE data (mean catch in numbers/net/day) indicated it was a stronger year class

than were the 1970 and 1971 cohorts. During the 5 years (1969-1973) the 1966 cohort persisted in the fishery, CPUE was 132 for 21,557 net days. In contrast, the CPUE for the 1970 cohort was 118 for 20,268 net days during the 5 year period 1973-1977; CPUE was 119 for 16,685 net days for the 1971 cohort which persisted for 4 years, 1975-1978.

Prior to the 1972 cohort, which first recruited to the fishery in 1976, total year-class contributions to the alewife fishery in the Potomac River ranged from 251 to 635 MT (Table 2.21). Age 4 fish were a substantial proportion of these landings, particularly in the years 1973 through 1975. Total landings of the 1972, 1973 and 1974 cohorts dramatically decreased. The decline is attributed to low reproductive success, as indicated by the extremely low proportion of age 4 fish in the 1976, 1977 and 1978 landings. There was a modest increase in the proportion of age 4 biomass in the 1979 and 1980 landings. The precipitous drop in landings in 1976 was attributed to the decimation of the 1972 year class by Tropical Storm Agnes (Loesch and Kriete 1976). Reasons for continued poor year-class strength are unknown, but may include such factors as discussed in species composition.

The same general patterns discussed above are reflected in the findings for the blueback herring fishery in the Potomac River (Table 2.22), and for both river herring species in the Rappahannock River fishery (Tables 2.23 and 2.24).

Mortality Estimates

Mortality estimates for river herring in Virginia were previously made. Tsimenides (1970) estimated instantaneous total mortality (Z), fishing mortality (F), and natural mortality (M) of alewives in the Rappahannock and Potomac rivers. He defined cohorts as subunits of a year

class based on sex and spawning history. Hoagman et al. (1973) estimated annual mortality rates (A) by pooling all catch data for sexes, species (alewives and blueback herring), and the above rivers. However, they defined a cohort solely on the basis of spawning history; thus, their cohorts contained two or more year classes.

Using both the method of Chapman and Robson (1960) and $\log_e$ of the ratio of successive couplets of CPUE for alewife cohorts, Tsimenides (1970) estimated mean Z's of 0.594 for males and 0.556 for females in the Rappahannock River for the years 1965-1969; respective values for the Potomac River were 0.558 and 0.513. Estimates of A by Hoagman et al. (1973), for the years 1965-1972, ranged from 0.372 to 0.871 (Z from approximately 0.47 to 2.05).

In our present study, a quick estimate of Z and A was made for alewives and blueback herring from the constants of the von Bertalanffy (1938) equation (K and L_∞) derived by Lipton (1979) and Travelstead (1980), and from the length at entry into the exploited phase (L_c) and mean length in the catch ($\bar{L}$). The expression, derived by Beverton and Holt (1956) is:

$$Z = K\ (L_\infty - \bar{L})/(\bar{L} - L_c)$$

For alewives, the values of Z and A were 1.164 and 0.687 for males when complete recruitment of a cohort was assumed to be age 5; the respective values for females were 0.891 and 0.589. Estimates of Z and A for male blueback herring were 0.912 and 0.598, and for females, 0.855 and 0.574. These estimates were considered preliminary because the validity of the model necessitates an assumption of a steady state.

Changes in fishing effort in the pound net fisheries for river herring have been documented in this report (Job 1) and in our past annual reports. In our next effort to estimate mortality rates, a model which utilizes changing effort and, thus, varying total mortality, was chosen. The model is, on an annual time basis:

$$Z = M + qf$$

where the regression coefficient q is the catchability constant, f is effort (net days), and the product $q \cdot f = F$. In our initial application of this model to Potomac River catches, Tsimenides' (1970) definition of a cohort was used, i.e., a cohort was defined by species, year class, sex, and spawning history. The results were unsatisfactory. Estimates of Z from the $\log_e$ of CPUE ratios were highly variable, some were even negative. The main problem appeared to be sample size. Most often there were low numbers in a sample after partitioning a year class by sex and spawning history. The problem is due, in part, to the initial numbers aged, incomplete recruitment of age 4 fish and few age 7 and 8 fish in the stock. Also, apparently due to the effects of Tropical Storm Agnes upon their development, the 1972 year class exhibited a different pattern of recruitment. CPUE data of alewives and blueback herring increased each year during their persistence in the fishery. To obtain greater numbers at age, sexes were pooled, and we assumed that total year-class recruitment to the fishery occurred at age 5. Although our long-term data indicate rare occurrences of virgins at age 6, we believe the assumption incurs no greater degree of error (perhaps less) than that associated with reading spawning checks on scales. Pooling of the data, presently limited to blueback herring, for the year classes 1962-1974, eliminated negative estimates of Z. However,

some estimates of Z were still unrealistic, i.e., relatively low values of Z (≤ 0.3) were associated with years of high effort, and relatively large values of Z (≥ 2.5) were associated with low effort. Arbitrarily, these estimates were omitted. Thirteen of 22 possible estimates of Z for ages 5 and 6 remained; of the retained estimates, ten formed five annual pairs of Z for ages 5 and 6. A paired t test was not significant for the mean difference between the paired Z values ($P>0.60$); thus, Z was assumed not to be age specific for ages 5 and 6. The regression of Z on effort gave estimates of $M = 0.6605$, and $q = 0.00018$. However, significance of the regression coefficient (q) was associated with a high probability of a Type I error ($\alpha = 0.30$). Annual mean values of Z, weighted by CPUE at age, regressed on effort, lowered the level of significance ($\alpha = 0.22$) and the estimate of the natural mortality rate ($M = 0.5075$); the estimate of the catchability coefficient increased slightly ($q = 0.00021$). These estimates of mortality rates are not considered very reliable because of the paucity of data, in general, and the subjective selection of data for the analyses. The analyses will continue. The Rappahannock River catch data will be added to the Potomac River data. There is no evidence for separate anadromous alewife and river herring stocks in Chesapeake Bay, and annual changes in the proportion of a stock spawning in a given river may change due to varying environmental conditions, say, water temperature and freshwater runoff. Annual changes in the proportion of a stock spawning in a river would produce the analytical problems encountered in the present analysis. Ideally, catch and effort data should be considered for all rivers and the Bay, but this information is not available. However, the Rappahannock and Potomac rivers constitute the major fisheries for river herring in the region, and pooling of the data should enhance our analyses.

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Table 2.1. Summary of sample data from the Alosa commercial fisheries during the 1980 spawning run in major Virginia tributaries to Chesapeake Bay.

River and Month	Alewife		Blueback		American shad	
	Male	Female	Male	Female	Male	Female
James						
March	34	22	13	5	26	74
April	57	38	147	82	15	85
York						
March	19	21	78	30	19	81
April	32	38	76	89	1	99
May	2	2	150	154		
Rappahannock						
March	87	70	77	22	30	70
April	10	19	137	268		
May	9	7	154	101		
Potomac						
April	5	9	168	217	43	40
May	17	59	208	178		
Totals (M&F)	557		2,354		583	

Table 2.2. River herring catches in the North Carolina and Virginia inshore fisheries and the foreign offshore fishery in ICNAF Area 6.

Year	Catch(metric tons*) North Carolina	Virginia	Foreign
1966	5,677	12,941	
1967	8,383	12,746	981
1968	7,040	14,657	1,075
1969	8,962	13,807	10,474
1970	5,225	8,637	6,052
1971	5,769	4,664	9,442
1972	5,996	4,740	4,974
1973	3,594	4,203	2,452
1974	2,816	6,050	2,817
1975	2,699	5,152	1,341
1976	2,903	1,839	1,554
1977	3,855	630	
1978	2,996	965	
1979	2,322	766	
1980	2,820	537	

*MT = 2,205 lb.

Table 2.3. Year-class frequency of alewives (sexes pooled) in the James River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	73.	2	1.9	1.9	1.9
	74.	10	9.3	9.3	11.1
	75.	48	44.4	44.4	55.6
	76.	48	44.4	44.4	100.0
	TOTAL	108	100.0	100.0	

MEAN	75.315	STD ERR	0.069	MEDIAN	75.375
MODE	75.000	STD DEV	0.719	VARIANCE	0.517
KURTOSIS	0.555	SKEWNESS	-0.861	RANGE	3.000
MINIMUM	73.000	MAXIMUM	76.000		
VALID CASES	108	MISSING CASES	0		

Table 2.4. Year-class frequency of blueback herring (sexes pooled) in the James River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	72.	1	0.8	0.8	0.8
	73.	6	5.0	5.0	5.8
	74.	16	13.2	13.2	19.0
	75.	70	57.9	57.9	76.9
	76.	28	23.1	23.1	100.0
	TOTAL	121	100.0	100.0	

MEAN	74.975	STD ERR	0.073	MEDIAN	75.036
MODE	75.000	STD DEV	0.801	VARIANCE	0.641
KURTOSIS	1.508	SKEWNESS	-0.946	RANGE	4.000
MINIMUM	72.000	MAXIMUM	76.000		
VALID CASES	121	MISSING CASES	0		

Table 2.5. Year-class frequency of alewives (sexes pooled) in the York River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	74.	9	10.5	10.5	10.5
	75.	37	43.0	43.0	53.5
	76.	40	46.5	46.5	100.0
	TOTAL	86	100.0	100.0	

MEAN	75.360	STD ERR	0.072	MEDIAN	75.419
MODE	76.000	STD DEV	0.667	VARIANCE	0.445
KURTOSIS	-0.677	SKEWNESS	-0.565	RANGE	2.000
MINIMUM	74.000	MAXIMUM	76.000		
VALID CASES	86	MISSING CASES	0		

Table 2.6. Year-class frequency of blueback herring (sexes pooled) in the York River commercial fishery samples, 1980

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	73.	2	1.1	1.1	1.1
	74.	14	7.6	7.6	8.7
	75.	102	55.4	55.4	64.1
	76.	65	35.3	35.3	99.5
	77.	1	0.5	0.5	100.0
	TOTAL	184	100.0	100.0	

MEAN	75.266	STD ERR	0.048	MEDIAN	75.245
MODE	75.000	STD DEV	0.653	VARIANCE	0.426
KURTOSIS	0.596	SKEWNESS	-0.452	RANGE	4.000
MINIMUM	73.000	MAXIMUM	77.000		
VALID CASES	184	MISSING CASES	0		

Table 2.7. Year-class frequency of alewives (sexes pooled) in the Rappahannock River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	74.	17	10.7	10.7	10.7
	75.	48	30.2	30.2	40.9
	76.	88	55.3	55.3	96.2
	77.	6	3.8	3.8	100.0
	TOTAL	159	100.0	100.0	

MEAN	75.522	STD ERR	0.058	MEDIAN	75.665
MODE	76.000	STD DEV	0.736	VARIANCE	0.542
KURTOSIS	-0.195	SKEWNESS	-0.607	RANGE	3.000
MINIMUM	74.000	MAXIMUM	77.000		
VALID CASES	159	MISSING CASES	0		

Table 2.8. Year-class frequency of blueback herring (sexes pooled) in the Rappahannock River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	72.	2	0.6	0.6	0.6
	73.	10	3.2	3.2	3.8
	74.	33	10.4	10.4	14.2
	75.	228	71.9	71.9	86.1
	76.	43	13.6	13.6	99.7
	77.	1	0.3	0.3	100.0
	TOTAL	317	100.0	100.0	

MEAN	74.956	STD ERR	0.037	MEDIAN	74.998
MODE	75.000	STD DEV	0.659	VARIANCE	0.435
KURTOSIS	3.713	SKEWNESS	-1.086	RANGE	5.000
MINIMUM	72.000	MAXIMUM	77.000		
VALID CASES	317	MISSING CASES	0		

Table 2.9. Year-class frequency of alewives (sexes pooled) in the Potomac River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	74.	2	2.6	2.6	2.6
	75.	26	33.3	33.3	35.9
	76.	50	64.1	64.1	100.0
	TOTAL	78	100.0	100.0	

MEAN	75.615	STD ERR	0.061	MEDIAN	75.720
MODE	76.000	STD DEV	0.540	VARIANCE	0.292
KURTOSIS	-0.078	SKEWNESS	-0.985	RANGE	2.000
MINIMUM	74.000	MAXIMUM	76.000		
VALID CASES	78	MISSING CASES	0		

Table 2.10. Year-class frequency of blueback herring (sexes pooled) in the Potomac River commercial fishery samples, 1980.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	73.	5	1.5	1.5	1.5
	74.	22	6.8	6.8	8.3
	75.	256	79.0	79.0	87.3
	76.	34	10.5	10.5	97.8
	77.	7	2.2	2.2	100.0
	TOTAL	324	100.0	100.0	

MEAN	75.049	STD ERR	0.031	MEDIAN	75.027
MODE	75.000	STD DEV	0.565	VARIANCE	0.320
KURTOSIS	4.509	SKEWNESS	0.219	RANGE	4.000
MINIMUM	73.000	MAXIMUM	77.000		
VALID CASES	324	MISSING CASES	0		

Table 2.11. Summary of mean and modal ( ) age data for river herring in the Virginia commercial fishery, 1977 - 1980.

River	Alewife				Blueback			
	1977	1978	1979	1980	1977	1978	1979	1980
James	5.4(5)	5.5(5-6)	4.0(4)	4.7(4-5)	5.7(6)	6.3(6)	4.8(4)	5.0(5)
Pamunkey[1]	5.7(5-6)	5.6(5-6)			6.0(6)	5.6(5-6)		
York	5.2(5)	5.4(5-6)	4.1(4)	4.6(4-5)	5.8(6)	5.8(6)	4.5(4)	4.7(5)
Rappahannock	5.6(5-6)	5.6(5-6)	4.0(4)	4.5(4)	5.8(6)	6.0(6)	4.5(4)	5.0(5)
Potomac	5.5(5-6)	5.6(5-6)	4.4(4-5)	4.4(4)	6.0(6)	6.1(6)	4.3(4)	5.0(5)

[1]No river herring fishery in 1979.

Table 2.12. Age frequency of alewives in the Rappahannock River pound net fishery samples, 1968-1980.

Year	Metric Tons	Age frequency (%)						
		3	4	5	6	7	8	9
1968	566.42	8.7	33.3	39.1	12.6	5.2	0.8	0.3
1969	110.12	12.0	40.4	23.3	18.5	3.4	1.0	1.4
1970	164.86	4.7	44.5	28.7	13.3	7.5	1.2	
1971	195.03	2.3	29.6	48.3	15.7	3.2	0.9	
1972	200.41	4.4	27.2	30.2	25.5	9.0	2.9	0.7
1973	150.93	0.6	53.8	26.4	12.5	5.3	1.3	0.2
1974	215.84	0.3	62.1	25.9	8.7	0.5	2.5	
1975	72.23	1.7	82.6	13.4	1.6	0.6	0.1	
1976	43.85		4.9	57.9	32.9	3.9	0.3	
1977	84.69		2.9	42.7	48.7	5.1	0.2	0.4
1978	130.80		4.5	43.6	41.8	8.7	1.4	
1979	56.02	33.2	35.5	26.5	4.3	0.5		
1980	23.28	3.8	55.3	30.2	10.7			

Table 2.13. Age frequency of blueback herring in the Rappahannock River pound net fishery samples, 1968-1980.

Year	Metric Tons	Age frequency (%)						
		3	4	5	6	7	8	9
1968	184.50	5.8	48.8	26.0	10.9	7.0	1.2	0.4
1969	170.01	6.7	53.0	24.9	9.1	3.5	2.5	0.4
1970	46.42	2.1	54.9	31.8	8.0	1.7	1.4	
1971	202.11	0.5	35.7	53.0	9.0	1.6	0.1	0.1
1972	133.75		28.1	39.5	24.8	6.4	1.3	
1973	241.51	0.4	49.0	30.7	15.5	3.7	0.7	
1974	130.47	0.2	42.9	35.4	15.7	4.6	1.2	
1975	171.92	0.6	85.4	11.6	2.0	0.3		
1976	67.89	0.1	3.5	53.1	39.6	3.6	0.1	
1977	209.16		2.5	42.1	51.2	4.1		
1978	381.73		1.3	22.2	55.3	20.5	0.5	0.1
1979	423.63	4.0	54.1	30.1	10.0	1.8		
1980	195.35	0.3	13.6	71.9	10.4	3.2	0.6	

Table 2.14. Age frequency of alewives in the Potomac River pound net fishery samples, 1968-1980.

Year	Metric Tons	Age frequency (%)						
		3	4	5	6	7	8	9
1968	687.76	8.7	47.8	4.3	39.1			
1969	265.44	53.5	32.6	4.7	9.3			
1970	214.81	7.4	66.3	16.8	3.2	2.1	2.1	2.1
1971	358.56	2.6	32.5	53.0	9.9	2.0		
1972	734.70	12.1	30.4	22.1	24.3	6.8	3.6	0.7
1973	249.94	2.8	58.9	22.8	8.5	5.3	1.6	
1974	294.34		86.5	9.0	2.7	1.8		
1975	843.02	2.7	80.7	15.1	0.6	0.9		
1976	312.53		2.0	37.6	50.7	8.7	1.0	
1977	34.67		6.3	40.3	50.7	2.8		
1978	49.74		3.5	45.2	40.0	11.3		
1979	11.52		16.4	36.1	37.7	9.8		
1980	34.00		64.1	33.3	2.6			

Table 2.15. Age frequency of blueback herring in the Potomac River pound net fishery samples, 1968-1980.

Year	Metric Tons	Age frequency (%)						
		3	4	5	6	7	8	9
1968	2,745.67	1.3	28.3	38.1	22.4	7.6	1.8	0.4
1969	1,288.58	9.5	50.0	27.6	8.1	4.8		
1970	2,576.70	1.5	65.7	18.2	11.0	2.1	1.5	
1971	2,299.67	0.6	43.4	45.5	9.7	0.6	0.3	
1972	1,409.46	0.3	40.1	30.9	22.2	5.1	1.5	
1973	378.74		27.7	42.9	22.9	5.2	1.3	
1974	1,304.33		81.9	12.2	4.0	1.5	0.5	
1975	2,048.29		86.1	11.6	1.1	1.1	0.2	
1976	431.99		1.6	22.8	54.5	19.6	1.3	0.3
1977	179.96		1.8	30.2	61.9	6.2		
1978	610.47		0.3	17.8	52.9	25.5	3.5	
1979	437.15	6.3	62.9	21.5	7.8	1.0	0.5	
1980	249.98	2.2	10.5	79.0	6.8	1.5		

Table 2.16. Year-class frequency of American shad in the Virginia commercial fishery, 1980.

Sex	Year Class	River				Total	Frequency (%)
		James	York	Rapp.	Potomac		
Male	1972				2	2	1.6
	1973			2	4	6	4.8
	1974	6	4	11	17	38	30.1
	1975	29	11	13	16	69	54.8
	1976	2	4	3	2	11	8.7
	Total	37	19	29	41	126	
Female	1972		1		5	6	1.4
	1973	15	13	8	8	44	10.1
	1974	68	81	31	15	195	44.9
	1975	64	76	29	9	178	41.0
	1976	2	6		3	11	2.5
	Total	149	177	68	40	434	

Table 2.17. Age frequencies of American shad in samples from the Virginia commercial fishery, 1977-1980.

Sex	Year	Age 4	5	6	7	8	Mean age	Modal age
Male	1977	46	58	17	5	2	4.9	4-5
	1978	3	68	102	13	1	5.6	6
	1979	7	25	53	9	1	5.7	6
	1980	11	69	38	6	2	5.3	5
Test of independence: X^2 = 136.7 with 12 df; P<0.0001								
Female	1977	53	433	190	15	2	5.2	5
	1978	4	138	389	42	0	5.8	6
	1979	6	75	179	56	5	5.9	6
	1980	11	178	195	44	6	5.7	5-6
Test of independence: X^2 = 389.1 with 12 df; P<0.0001								

Table 2.18. Length (mm) and weight (g) statistics for river herring in the 1980 Virginia fisheries.

River		Alewife						Blueback					
		Male			Female			Male			Female		
		N	Mean	Std. Error	N	Mean	Std. Error	N	Mean	Std. Error	N	Mean	Std. Error
James	Length	91	247.4	0.874	68	259.8	1.176	160	246.1	0.760	87	255.6	1.040
	Weight	91	229.2	2.784	68	268.7	5.390	160	201.9	2.422	85	232.1	3.793
York	Length	53	249.6	1.491	62	264.3	1.666	305	247.3	0.535	273	256.8	0.692
	Weight	53	199.4	5.538	62	237.1	6.426	305	188.4	2.060	273	205.1	2.665
Rappahannock	Length	106	249.8	0.921	96	262.1	1.154	368	247.1	0.485	390	255.4	0.516
	Weight	106	224.4	3.014	96	274.1	5.229	368	189.0	1.854	390	213.6	2.223
Potomac	Length	22	249.5	1.709	68	257.6	1.053	375	246.4	0.484	396	256.5	0.667
	Weight	22	192.7	6.264	68	203.5	5.025	374	191.1	1.719	396	227.3	2.179

Table 2.19. Chi square analysis of alewife sex ratios in the 1980 Virginia fisheries.

Rivers	Sex M	Sex F	Total	X^2	df	Probability
James	91	68	159	3.33	1	P>0.05
York	53	62	115	0.70	1	P>0.30
Rappahannock	106	96	202	0.49	1	P>0.40
Potomac	22	68	90	23.51	1	P<0.001
Total X^2				28.03	4	
Pooled	272	294	566	0.86	1	P>0.30
Homogeneity				27.17	3	P<0.001
			Potomac data removed			
	91	68	159	3.33	1	
	53	62	115	.70	1	
	106	96	202	.49	1	
Total X^2				4.52	3	
Pooled	250	226	476	1.21	1	P>0.10
Homogeneity				3.31	2	P>0.20

Table 2.20. Chi square analysis of blueback herring sex ratios in the 1980 Virginia fisheries.

Rivers	Sex M	Sex F	Total	X^2	df	Probability
James	160	87	247	21.57	1	P<0.0001
York	305	273	578	1.77	1	P>0.10
Rappahannock	368	390	758	0.64	1	P>0.30
Potomac	374	396	770	0.62	1	P>0.30
Total X^2				24.60	4	P<0.001
Pooled	1207	1146	2353	1.58	1	P>0.20
Homogeneity				23.02	3	P<0.001
			James data removed			
	305	273	578	1.77	1	
	368	390	758	0.64	1	
	374	396	770	0.62	1	
Total X^2				3.03	3	
Pooled	1047	1059	2106	0.07	1	P>0.70
Homogeneity				2.96	2	P>0.20

Table 2.21. Annual and total year-class contributions (MT) to the Potomac River alewife fishery, 1968-1980.

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.93												
1969	97.51	124.05											
1970	38.69	136.99	16.01										
1971	37.55	190.93	115.21	7.89									
1972	61.26	169.34	180.59	210.70	81.24								
1973	5.44	13.84	21.22	58.88	144.51	6.10							
1974			5.29	8.04	26.51	254.45							
1975				13.44	6.81	62.34	298.17	1.86					
1976				1.47	15.26	72.96	49.97	1.98					
1977					0.04	2.16	16.66	12.56	3.04				
1978							8.41	17.31	20.51	2.16			
1979									1.26	1.39	7.11	1.73	
1980										0.56	14.86	18.15	
Year Class Total	251.38	635.15	338.32	300.42	274.37	398.01	373.21	33.71	24.81	4.11	21.97	19.88	

Table 2.22. Annual and total year-class contributions (MT) to the Potomac River blueback fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	20.03												
1969	646.78	99.65											
1970	492.09	1671.00	23.95										
1971	203.66	1053.98	1000.96	16.24									
1972	74.38	294.52	439.86	576.54	2.56								
1973	2.11	20.61	67.21	151.59	135.26	1.95							
1974		7.06	18.85	51.80	157.71	1068.90							
1975			0.81	37.13	116.23	335.23	1560.10	0.83					
1976			3.54	4.70	98.72	233.70	87.33	4.20					
1977					1.02	31.79	108.67	36.25	1.43				
1978						26.27	157.82	318.41	106.39	1.54			
1979									37.10	79.67	285.31	34.16	
1980									4.22	28.79	213.49	23.72	1.67
Year Class Total	1439.05	3146.82	1555.18	838.00	511.50	1697.84	1913.92	359.69	149.14	110.00	498.80	57.88	1.67

Table 2.23. Annual and total year-class contributions (MT) to the Rappahannock River alewife fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	49.79												
1969	44.49	13.21											
1970	47.31	73.36	7.75										
1971	30.62	94.20	57.73	4.48									
1972	18.04	51.10	60.52	54.51	8.82								
1973	1.96	8.00	18.87	39.84	81.20	0.90							
1974		5.40	1.08	18.78	55.90	134.04	0.65						
1975			0.07	0.43	1.16	9.68	59.66	1.23					
1976				0.13	1.71	14.43	25.39	2.15					
1977				0.34	0.17	4.32	41.24	36.16	2.46				
1978						1.83	11.38	54.67	57.03	5.89			
1979								0.28	2.41	14.84	19.89	18.60	
1980										2.49	7.03	12.87	0.88
Year Class Total	192.21	245.27	146.02	118.51	148.96	165.20	138.32	94.49	61.90	23.22	26.92	31.47	0.88

Table 2.24. Annual and total year-class contributions (MT) to the Rappahannock River blueback fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.68												
1969	90.10	11.39											
1970	14.76	25.48	0.97										
1971	18.19	107.12	72.15	1.01									
1972	8.56	33.17	52.83	37.58									
1973	1.69	8.94	37.34	74.14	118.34	0.97							
1974		1.56	6.00	20.48	46.19	55.97	0.26						
1975				0.52	3.44	19.94	146.82	1.03					
1976				0.07	2.44	26.88	36.05	2.38	0.07				
1977						8.58	107.09	88.06	5.23				
1978					0.38	1.91	78.25	211.10	84.74	4.96			
1979								7.62	42.36	127.51	229.18	16.94	
1980								1.17	6.25	20.32	140.46	26.57	0.59
Year Class Total	143.98	187.66	169.29	133.80	170.79	114.25	368.47	311.36	138.65	152.79	369.64	43.51	0.59

Job 3. Annual Index of Juvenile Alosa Abundance

SUMMARY

1. The major Virginia Alosa nursery areas were each sampled three times in 1980, and the findings were compared to the 1979 survey data.

2. An index of abundance was defined as the maximal catch-per-unit-effort (CPUE). There was no overall significant difference between the 1979 and 1980 indices for blueback herring, but there were offsetting changes. Indices for blueback herring in the James and Potomac rivers increased 33 and 498%, respectively, in 1980, while the other river systems decreases ranged from 8 to 94%. Alewife index values were lower in 1980 in all river systems sampled, with decreases ranging from 24 to 88%. Maximal CPUE for American shad occurred in the York River system (Mattaponi and Pamunkey rivers) in both years, but the index decreased 82% in the Pamunkey River in 1980.

3. Growth curves were constructed from the 1979 juvenile fork length data. Growth appeared to be maximal in the Potomac River and minimal in the Mattaponi River. The effects on growth estimates of juvenile recruitment to the sampling gear and the downstream drift of larger fish were discussed.

4. Instantaneous daily mortality rates (Md) of juvenile Alosa were calculated for 1979 and 1980. For alewives in 1979, Md values ranged from 0.033 to 0.040. American shad Md estimates in 1979 were 0.040 and 0.060 in the Mattaponi and Pamunkey rivers, respectively. Excluding the Chickahominy River, Md estimates for blueback herring in 1979 ranged from 0.034 to 0.048. The Md estimate for Chickahominy blueback herring was relatively high, 0.067; we suspect the estimate is inflated due to emigration of fish from the Chickahominy River. Estimates of Md in 1980 for alewives and blueback herring were not significantly different from the 1979 values, but were somewhat more variable. American shad Md estimates in the Mattaponi and Pamunkey rivers increased in 1980. We suspect these estimates are also inflated because of emigration of the larger fish between the first and second sampling periods which occurred later in 1980 than in 1979.

Job 3. Annual Index of Juvenile Alosa Abundance

INTRODUCTION

The important long-term objectives of assessing year-class strength are to determine if there is a relationship between the annual index of abundance and future recruitment, and to determine if there is a periodicity of strong year classes.

MATERIALS AND METHODS

Prior to 1978, indices (CPUE) of juvenile (young-of-the-year) Alosa were derived from single, daytime trawl surveys in each river. Implicit in that sampling scheme were the assumptions that the proportion of juvenile stock available to the gear at the time of sampling was constant year to year, and fish availability was independent of light intensity. Loesch et al. (in press), however, reported diel migratory activities by juvenile anadromous Alosa, and an association between sky-opacity index values and daytime surface catches of blueback herring. Their findings suggest that the juveniles (or their prey) are negatively phototropic. Additionally, Kriete and Loesch (1980) found that a bow-mounted pushnet greatly enhanced the catchability of juvenile Alosa relative to the trawls previously used. Based on these findings, nighttime sampling commenced in 1978, using both surface trawls and the pushnet. Catch data were adjusted to a constant volume of water filtered, determined from net opening and distance traveled. In 1979, flow meters were installed in the pushnet and trawls for more precise estimates of the

volume of water filtered in standard 5-min samples. The pushnet was used exclusively for sampling juvenile abundance. The trawls and pushnet were used in a comparison study of gear efficiency in order to adjust existing trawl catch data to equivalent pushnet values. Another major change in 1979 was that the frequency of sampling in each river was increased from one to six periods between June and October. The basic sampling scheme in 1979 was a stratified random sampling plan with allocation of effort a function of stratum surface area. Details of the sampling plan were presented by Loesch et al. (1979); the scheme was repeated in 1980, but differed in that each river was sampled only three times, once each in July, August, and September, and the number of strata sampled was reduced.

With the institution of multiple periods of sampling, the juvenile index was redefined as the maximal mean CPUE derived from the total catch in a nursery zone. Subsequent declining estimates of the index, that clearly preceded the onset of the juvenile Alosa seaward migration, were used in conjunction with the maximal value to estimate the instantaneous natural mortality rate (M). The $\log_e$ of the ratio of maximal CPUE to a subsequent CPUE was used to calculate M when there was only one usable CPUE subsequent to the maximal value. Division by the number of days elapsed from the maximal CPUE (day 1) to the subsequent CPUE gave the daily instantaneous rate of natural mortality (Md). With two or more usable CPUE values following the maximal CPUE, catch curves were used to derive Md.

Increases in mean fork length were used to calculate juvenile Alosa growth. The range in length of a species in a given sampling

period is rather restricted and preliminary analysis of blueback herring data by strata indicated that a standard error equal to 5% of the mean length could be obtained with a random subsample of about five fish. Arbitrarily, 15 fish per stratum were used.

RESULTS AND DISCUSSION

Relative Abundance

Juvenile CPUE data by strata and the index values for each of the six rivers sampled in 1979 are included in the present report (Tables 3.1-3.6) for comparison with the 1980 findings (Tables 3.7-3.12).

Based on the 1979 findings, Loesch et al. (1979) concluded: (1) blueback herring CPUE greatly exceeded those for alewives and American shad; (2) blueback herring CPUE reached a maximum in July or early August then declined. In contrast, alewife and American shad CPUE were generally greatest in June or early July; and (3) juveniles were more widely distributed in June and early July, had greater upriver concentrations in the summer, and then moved downriver in September and October as a first stage of their seaward migration. The superiority of the blueback herring CPUE is probably, in part, due to differences in Alosa phototropic behavior (Loesch et al. in press); however, commercial landings indicate that blueback herring are more abundant than alewives. Differences in the time of maximal CPUE stem from the differences in time when the bulk of each species spawns. Changes in the distribution of the juveniles probably reflect hydrological changes; apparently, juveniles move upriver in the summer

because of the lessening of freshwater runoff and the ensuing encroachment of saline water.

The 1980 findings for juvenile Alosa distributions and relative abundance among rivers were similar to the 1979 findings. With an exception in the Mattaponi River, blueback herring were again the dominant Alosa species in the samples. For both years, the larger indices (maximal CPUE values) for blueback herring occurred (in decreasing order) in the Rappahannock, Chickahominy, and Pamunkey rivers. Alewife indices were largest for the Rappahannock River with the York River system (Mattaponi and Pamunkey rivers) values a distinct record in both years. American shad indices, in both years, were highest in the York River system, but the index values were extremely low in the other systems.

There were also differences in the 1979 and 1980 findings. A paired t test of the 1979 and 1980 maximal CPUE values for blueback herring was nonsignificant ($P>0.20$), but the nonsignificance was due to large, offsetting changes of the index values. The indices for the James and Potomac rivers blueback herring increased 33 and 498%, respectively, in 1980, while in the other river systems, decreases in index values ranged from 8 to 94%. Alewife index values were lower in 1980 in all river systems, with decreases ranging from 24 to 88%. Although the maximal CPUE for American shad occurred in the York River system in both years, the value decreased 82% in the Pamunkey River in 1980.

It is our intention, after the establishment of a data base of maximal CPUE's, to investigate the applicability of a multiple regression model for determining the relationship of relative year-class strength of juveniles and environmental variables to year-class recruitment. A consideration of residual mean squares or Mallows' criterion (see Snedecor and Cochran 1980) could indicate that a subset of the present six rivers sampled would be sufficient. The appropriateness of a pooled index value for all rivers, derived from weighting each index value by the area of the nursery zone, will also be considered.

Growth

Growth curves were constructed from the 1979 juvenile fork length data (Figs. 3.1 and 3.2). Two aspects of these curves must be interpreted from the life history of the Alosa. During the season, there is a tendency for the larger fish to migrate downstream (Loesch 1969, Marcy 1976). Thus, growth will be underestimated if these individuals leave the nursery zone. As indicated for the blueback herring in the Potomac River (Fig. 3.2), the maximal mean length may not occur in the last sampling period. The other aspect of Alosa behavior that affects estimates of juvenile growth (and mortality) is their protracted spawning period. Spawning intensity builds to a maximum and then decreases through approximately a three-month period. Juveniles collected in June through early August are primarily products of the early spawners. About mid-August, the juveniles produced by the bulk of the spawners become susceptible to capture by

the pushnet. The result of this recruitment is an apparent decrease in the growth rate, or as indicated for alewives (Fig. 3.1), a decrease in mean length. This apparent "negative growth" was noted for juvenile blueback herring in the Susquehanna River (Whitney 1961) and in the Connecticut River (Loesch 1969); it is also apparent in Marcy's (1976) juvenile American shad growth curve (his Fig. 46).

Visual evaluation of the growth curve, with emphasis on the first three sampling periods, indicated that blueback herring length was maximal in the Potomac River and minimal in the Mattaponi River. Intermediate sizes, ranked from highest to lowest, occurred in the James, Pamunkey and Rappahannock (about equal), and Chickahominy rivers. The ranking of rivers for alewife size was Potomac, Rappahannock, Pamunkey and Mattaponi. American shad fork lengths were consistently larger in the Pamunkey River than in the Mattaponi River. The Mattaponi is the most pristine of the rivers sampled; this condition may reflect a lesser food supply and, consequently, account for the smaller observed mean lengths of the three Alosa species.

The problem of uneven recruitment of juveniles during the sampling periods precluded meaningful estimates of instantaneous growth. The problem also highlights the need to distinguish among juveniles spawned at reasonably different times. Past mark and recapture studies with juvenile Alosa have been unsuccessful (Loesch 1969, Marcy 1976). A future endeavor will be an analysis of size frequency distributions to determine if there are unique and persistent modal groups that are traceable.

Natural Mortality

Initially, catch curves were constructed for the three Alosa species where catch data were sufficient, i.e., for alewives in the Mattaponi, Pamunkey and Rappahannock rivers, for American shad in the Mattaponi and Pamunkey rivers, and for blueback herring in the six rivers sampled. Catch curves are characterized by an ascending left limb, a dome, and a descending right limb. The ascending left limb and the dome represent ages incompletely recruited; linearity of the descending right limb is considered as evidence that recruitment and natural mortality are adequately constant for application of the model (Ricker 1948, Royce 1972). When catch curves do not have a straight descending right limb, there is reason to suspect that recruitment or catchability varies, or that the population is not in equilibrium (Royce 1972). Ten of the 11 juvenile Alosa catch curves (Figs. 3.3-3.5) had an upward inflection in the descending right limb that corresponded to the period of depressed mean growth due to recruitment. Therefore, with three exceptions, the instantaneous daily mortality rate (Md) was calculated from the $\log_e$ of the ratio of $CPUE_t/CPUE_{t+1}$. The CPUE at time 't' was most often maximal CPUE. However, for blueback herring in the Rappahannock and Potomac rivers, t tests indicated that the CPUE values immediately after maximal CPUE were not significantly different from the maximal CPUE ($P>0.80$ in both analyses). Therefore, these values were used instead of the maximal CPUE. Additionally, for blueback herring in the James River, a consideration of the catch and growth curves indicated that the CPUE

values of a later period, 22 August-17 September, were the most appropriate. No CPUE values obtained in September or October for alewives and American shad were used to estimate mortality rates because these species are then in the process of their seaward migration.

Estimates of Md for alewives ranged from 0.033 to 0.040, with a mean of 0.036 (Table 3.13). Md was maximal for alewives in the Pamunkey River. Actual daily mortality (Ad) for alewives ranged from 3.2 to 3.9%. American shad Md estimates were 0.040 in the Mattaponi River and 0.060 in the Pamunkey River; respective Ad values were 3.9 and 5.8%. Excluding the Chickahominy River, Md estimates for blueback herring ranged from 0.034 to 0.048, with a mean of 0.040; Ad estimates ranged from 3.3 to 4.8%. The estimated values of Md and Ad for blueback herring in the Chickahominy River were relatively high, 0.067 and 6.5%, respectively. We believe these values are inflated because of emigration by the larger juveniles. Due to the relatively small nursery zone length, approximately 37 km, Chickahominy emigrants would soon enter the James River. If, in fact, there is a drift of the larger juveniles to the James River, it would account for the higher estimates of mortality rates, and the apparent slow growth of blueback herring in the Chickahominy River (Fig. 3.2). The relatively slow decline in CPUE in the James River from 10 July through 22 August (Table 3.1) could be the result of blueback herring emigration from the Appomattox and Chickahominy rivers and the large Jones Neck and Turkey Island oxbows. Like the James River, but unlike the other systems sampled, the Potomac River has a number of relatively large

tributaries in its nursery zone. The observed larger mean lengths of blueback herring in these two rivers could be due to differences in the availability of food in the nursery zones. However, with the probable exception of the Mattaponi River, the apparent superior growth in the James and Potomac rivers could, at least in part, result from disproportionate abundance of larger fish in the main streams due to emigration.

Present estimates of Md in 1979 are higher than those previously determined for the same data (Loesch et al. 1979). The initial determinations were influenced by recruitment because Md was calculated from the ratio of maximal CPUE and a CPUE determined after the mid-August recruitment.

Estimates of Md in 1980 (Table 3.14) for alewives and blueback herring (pooled) were not significantly different from the 1979 values (paired t test; $P>0.70$), but were somewhat more variable. The largest estimated Md, as in 1979, was for blueback herring in the Chickahominy River. Estimates of Md for American shad in 1980 increased in both the Mattaponi and Pamunkey rivers. However, the estimates may have been inflated due to emigration. Sampling did not commence in 1980 until about mid-July, but in 1979 maximal CPUE occurred in June (Tables 3.3 and 3.4).

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Table 3.1. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the James River for the period 21 June - 11 October, 1979.

Species	River Miles		CPUE June 21	July 10	July 31	Aug 22	Sept 17	Oct 11
Alewife	75-80				0.3			
	70-75				0.3			
	65-70			0.2	0			0.3
	60-65			0.1	0			
	55-60				0.2			
	50-55							
	45-50							
	40-45							
		$\bar{x}$		0.1	0.2			0.3
Blueback herring	75-80		11.0	32.0	50.7	14.3	6.7	
	70-75		19.3	63.0	49.5	79.8	10.0	
	65-70		51.5	30.2	98.8	96.7	18.5	4.1
	60-65		12.3	34.5	59.8	62.8	10.0	6.2
	55-60		26.0	76.3	17.3	22.2	19.0	36.0
	50-55		33.5	99.7	119.4	3.5	3.0	28.0
	45-50			135.7	26.4	2.8	2.0	16.0
	40-45			3.0	3.5			16.0
		$\bar{x}$	25.1	65.4	55.1	41.8	11.3	18.4
American shad	75-80							
	70-75		0.3					
	65-70		0.2					0.4
	60-65		0					
	55-60		0					
	50-55		0.5		0.3			
	45-50							
	40-45							
		$\bar{x}$	0.3		0.3			0.4

Table 3.2. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Chickahominy River for the period 21 June - 11 October, 1979.

Species	River Miles		CPUE June 21	July 12	Aug 2	Aug 21	Sept 17	Oct 11
Alewife	15-20		0.4	0.3	0.2	0.2	0.2	
	10-15				0.3			
	5-10				0.2			
	0- 5							
		$\bar{x}$	0.4	0.3	0.2	0.2	0.2	
Blueback herring	15-20		562.4	514.8	61.7	37.6	26.8	6.0
	10-15		187.9	604.2	111.8	29.0	9.4	4.3
	5-10		77.2	172.0	179.2	21.0	4.8	2.0
	0- 5		26.0	72.0	22.0	4.2	3.3	2.7
		$\bar{x}$	213.4	365.2	99.0	25.2	13.0	4.0
American shad (a)								

(a) Two American shad taken during the 21 June sampling period between miles 5-10.

Table 3.3. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Pamunkey River for the period 20 June - 9 October, 1979.

Species	River Miles		CPUE					
			June 20	July 9	July 30	Aug 20	Sept 12	Oct 9
Alewife	65-70		0.3	2.3	0.3			
	60-65		1.0	0	1.7	1.0		
	55-60		13.9	6.9	1.3	4.5		
	50-55		12.9	14.5	5.8	1.6	0.5	
	45-50		2.5	7.7	5.3	1.1	0	
	40-45			5.3	0.7		0.7	
	35-40			0.3			0.3	
	30-35						0.3	1.0
		$\bar{x}$	6.0	6.7	2.8	1.9	0.3	1.0
Blueback herring	65-70		2.6	2.6	21.3	90.6	18.5	
	60-65		31.1	9.3	20.3	181.0	26.0	
	55-60		447.5	151.6	93.2	27.7	8.0	1.0
	50-55		428.8	660.7	129.8	54.2	48.3	8.0
	45-50		80.0	132.6	136.3	70.2	17.3	10.0
	40-45			29.3	12.7		65.7	18.0
	35-40				33.0		82.0	12.0
	30-35						16.3	2.0
		$\bar{x}$	193.6	224.8	77.7	74.2	34.3	7.9
American shad	65-70		5.5	16.1	11.3	31.3	3.3	
	60-65		63.8	9.3	20.0	24.3	4.0	
	55-60		106.7	39.2	20.3	6.0	2.3	0.3
	50-55		66.6	16.1	9.0	2.7	1.0	0
	45-50		23.1	4.7	13.3	0.8	0	0
	40-45			9.4	0.3		0.7	0
	35-40			0.3	1.0		0	2.0
	30-35						1.0	0.5
		$\bar{x}$	57.4	17.3	12.5	9.0	1.6	0.4

Table 3.4. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Mattaponi River for the period 20 June - 9 October, 1979.

Species	River Miles		CPUE					
			June 20	July 9	July 31	Aug 20	Sept 12	Oct 9
Alewife	60-62		1.0	2.5	0.6			
	55-60		0.7	0	0	1.3		
	50-55		0.8	2.0	0			
	45-50		2.2	12.0	0.7		0.4	
	40-45			10.5	1.8		0.4	0.6
	35-40			8.0			1.8	1.1
	30-35			0.5			1.8	
		$\bar{x}$	1.2	6.0	0.4	1.3	0.9	0.9
Blueback herring	60-62		4.7	5.5	17.6		0.4	
	55-60		3.7	22.3	30.8	24.6	7.9	1.0
	50-55		6.8	129.3	32.8	30.1	6.9	4.0
	45-50		16.2	102.5	34.8	20.7	4.7	4.8
	40-45				51.0	2.8	21.4	12.3
	35-40					0.4	17.0	26.7
	30-35						6.2	7.0
		$\bar{x}$	8.3	73.0	31.1	17.4	10.1	12.2
American shad	60-62		61.0	25.0	31.7		0.4	
	55-60		29.3	18.3	12.3	18.7	12.8	
	50-55		40.7	17.0	15.2	4.0	4.0	2.6
	45-50		32.8	18.5	12.8	4.4	2.0	0.9
	40-45			18.0	7.9	3.5	2.9	0.3
	35-40			7.3			2.0	
	30-35						1.8	
		$\bar{x}$	38.1	17.0	16.8	7.6	4.3	1.1

Table 3.5. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Rappahannock River for the period 26 June - 15 October, 1979.

Species	River Miles		CPUE June 26	July 10	Aug 1	Aug 21	Sept 18	Oct 15
Alewife	85-90		22.0	53.7	138.0	2.5		
	80-85		65.2	88.7	39.0	7.2		
	75-80		70.8	55.3	22.0	8.0	1.5	
	70-75		67.5	29.3	3.3	7.0	1.0	
	65-70		88.7	17.3	9.0	5.5	2.0	1.0
	60-65		23.0	26.2	3.0	1.0	3.0	0.3
	55-60		21.2	16.5	3.8	1.6	4.0	0.5
	50-55		43.0	29.5	1.3	0.6	2.7	2.3
	45-50		22.0	3.8	3.0	4.0	0.5	
	40-45		17.5	4.8			4.0	
	35-40			0.4				
		$\bar{x}$	50.0	30.6	26.0	4.3	2.3	1.1
Blueback herring	85-90		556.0	852.5	919.5	307.5	7.0	
	80-85		222.5	972.4	1229.5	215.5	3.7	
	75-80		401.8	1734.7	1533.0	145.5	28.5	0.5
	70-75		333.3	846.8	1537.3	203.3	54.3	0
	65-70		655.7	892.5	1012.3	448.5	69.0	14.0
	60-65		773.3	354.4	169.8	608.5	121.5	24.3
	55-60		546.2	288.6	115.8	309.3	228.8	12.3
	50-55		873.3	1769.9	31.8	49.0	346.0	33.0
	45-50		330.0	175.6	8.0		60.5	18.0
	40-45		196.5	16.3			51.5	4.5
	35-40							
		$\bar{x}$	516.1	775.2	770.9	293.0	100.5	15.9
American shad	85-90			1.6				
	80-85		0.3	0				
	75-80		0.5	0				
	70-75		0	0				
	65-70		0	0				
	60-65		0.3	0.4				
	55-60		0					
	50-55		2.0					
	45-50							
	40-45							
	35-40							
		$\bar{x}$	0.5	0.4				

Table 3.6. Juvenile *Alosa* mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Potomac River for the period 26 June - 17 October, 1979.

Species	River Miles		June 26	July 16	Aug 6	Aug 28	Sept 19	Oct 17
Alewife	90-95		3.5	0.7		3.7		
	85-90		2.7	1.0	0.8	0.5	0.3	0.5
	80-85		3.6	1.4	0.5	0.8	0.2	0.5
	75-80		5.5	0.5	0.6	0.1	0.1	0
	70-75		2.4	0.8	0.5			1.2
	65-70			0.3				1.0
	60-65							0.3
		$\bar{x}$	3.5	0.8	0.6	0.8	0.2	0.6
Blueback herring	90-95		31.8	13.2		1.0		
	85-90		30.4	32.2	22.0	6.5	1.7	0.5
	80-85		16.8	11.0	6.1	7.5	4.8	1.0
	75-80		16.9	8.6	10.2	2.9	7.5	1.0
	70-75		15.8	22.6	3.2	0.2	2.5	4.0
	65-70		0.3	14.7	1.0			1.0
	60-65		0.9					4.8
		$\bar{x}$	19.6	16.8	8.1	3.8	4.9	3.7
American shad (a)								

(a) No American shad taken. (Erroneously reported as 1 American shad in 1979 report.)

Table 3.7. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the James River for July, August and September, 1980.

Species	River Miles	CPUE July	CPUE August	CPUE September
Alewife (a)				
Blueback herring	70-75	91.5	34.9	236.4
	65-70	32.4	167.4	140.7
	60-65	113.5	18.7	95.3
	55-60	65.0	92.3	7.8
	50-55	35.0	37.6	4.6
	45-50	15.0	4.1	
$\bar{x}$		58.4	55.3	86.8
American shad (b)				

(a) One alewife taken in July between miles 45-50.

(b) No American shad taken.

Table 3.8. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Chickahominy River for July, August and September, 1980.

Species	River Miles	CPUE July	CPUE August	CPUE September
Alewife (a)				
Blueback herring	15-20	264.5	18.3	27.5
	10-15	182.7	29.0	41.0
	5-10	154.9	6.2	34.2
	0- 5	15.9		0.4
	$\bar{x}$	154.5	17.8	28.1
American shad (b)				

(a) Five alewives taken (3 in July; 2 in August) between miles 15-20.

(b) No American shad taken.

Table 3.9. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Pamunkey River for July, August and September, 1980.

Species	River Miles	CPUE July	CPUE August	CPUE September
Alewife	55-60	4.4	0.7	
	45-50	2.9	1.7	0.2
$\bar{x}$		3.6	1.2	0.2
Blueback herring	65-70	116.0	36.0	87.9
	55-60	129.0	43.2	16.5
	45-50	58.6	37.5	15.2
	35-40	7.9		
$\bar{x}$		87.9	38.9	39.9
American shad	65-70	11.0	1.2	1.9
	55-60	9.4	0.7	1.5
	45-50	0.8	0.5	
$\bar{x}$		7.1	0.8	1.7

Table 3.10. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Mattaponi River for July, August and September, 1980.

Species	River Miles	CPUE July	CPUE August	CPUE September
Alewife	55-60	0.6		
	50-55	0.6		
	45-50	0.6		
	40-45	11.2	1.4	
	35-40	1.4		
	$\bar{x}$	2.9	1.4	
Blueback herring	55-60	10.5	0.6	3.8
	50-55	4.8	7.1	0
	45-50	2.6	2.9	1.6
	40-45	0.6	0.6	
	$\bar{x}$	4.6	2.8	1.8
American shad	55-60	66.9	3.6	3.5
	50-55	54.0	17.0	1.8
	45-50	30.9	23.1	0.6
	40-45	38.3	10.6	0.6
	35-40	3.8	1.5	(a)
	$\bar{x}$	38.8	11.2	1.6

(a) Not sampled.

Table 3.11. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Rappahannock River for July, August and September, 1980.

Species	River Miles	CPUE July	CPUE August	CPUE September
Alewife	80-85	51.1	9.5	11.9
	70-75	55.0	17.4	50.3
	60-65	21.1	38.9	6.6
	50-55	20.4	15.1	
	$\bar{x}$	38.0	20.2	22.9
Blueback herring	80-85	679.2	198.9	358.9
	70-75	1334.4	497.2	542.0
	60-65	570.1	317.9	301.9
	50-55	133.8	95.1	139.7
	$\bar{x}$	715.7	277.3	380.8
American shad (a)				

(a) No American shad taken.

Table 3.12. Juvenile Alosa mean catch-per-unit-of-effort (CPUE) and overall weighted mean ($\bar{x}$) in the Potomac River for July, August and September, 1980.

Species	River Miles	CPUE		
		July	August	September
Alewife	85-90	2.4		0.3
	80-85	5.0		0.6
	75-80	0.3	1.0	0.9
	70-75	0.3		0.4
$\bar{x}$		2.0	1.0	0.5
Blueback herring	85-90	119.2	27.6	72.4
	80-85	253.0	16.5	149.1
	75-80	79.1	117.7	50.9
	70-75	17.3	35.4	43.6
	65-70	(a)	9.0	0.3
$\bar{x}$		117.2	37.3	62.0
American shad (b)				

(a) Not sampled.

(b) No American shad taken.

Table 3.13. Estimates of instantaneous daily mortality (Md), actual daily mortality (Ad), and actual daily survival (Sd) rates for juvenile Alosa, 1979.

Species	River	Period	Md	Ad	Sd
Alewife	Mattaponi	9 Jul-20 Aug	0.036	0.035	0.965
	Pamunkey	9 Jul-30 Jul	0.040	0.039	0.961
	Rappahannock	26 Jun-10 Jul	0.033	0.032	0.968
American shad	Mattaponi	20 Jun-9 Jul	0.040	0.039	0.961
	Pamunkey	20 Jun-9 Jul	0.060	0.058	0.942
Blueback herring	James	22 Aug-17 Sep	0.048	0.047	0.953
	Chickahominy	12 Jul-21 Aug	0.067	0.065	0.935
	Mattaponi	9 Jul-20 Aug	0.034	0.033	0.967
	Pamunkey	9 Jul-30 Jul	0.040	0.039	0.961
	Rappahannock	1 Aug-21 Aug	0.046	0.045	0.955
	Potomac	16 Jul-28 Aug	0.034	0.033	0.967

Table 3.14. Estimates of instantaneous daily mortality (Md), actual daily mortality (Ad), and actual daily survival (Sd) rates for juvenile Alosa, 1980.

Species	River	Period	Md	Ad	Sd
Alewife	Mattaponi	14 Jul-4 Aug	0.033	0.032	0.968
	Pamunkey	7-14 Jul-5 Aug	0.041	0.040	0.956
	Rappahannock	10 Jul-5 Aug	0.023	0.023	0.977
American shad	Mattaponi	14 Jul-4 Aug	0.056	0.054	0.945
	Pamunkey	7-14 Jul-4 Aug	0.079	0.076	0.924
Blueback herring	Chickahominy	15 Jul-7 Aug	0.090	0.086	0.914
	Mattaponi	14 Jul-4 Aug	0.022	0.022	0.978
	Pamunkey	7-14 Jul-5 Aug	0.031	0.031	0.969
	Rappahannock	10 Jul-5 Aug	0.035	0.034	0.966
	Potomac	9 Jul-4 Aug	0.042	0.041	0.959

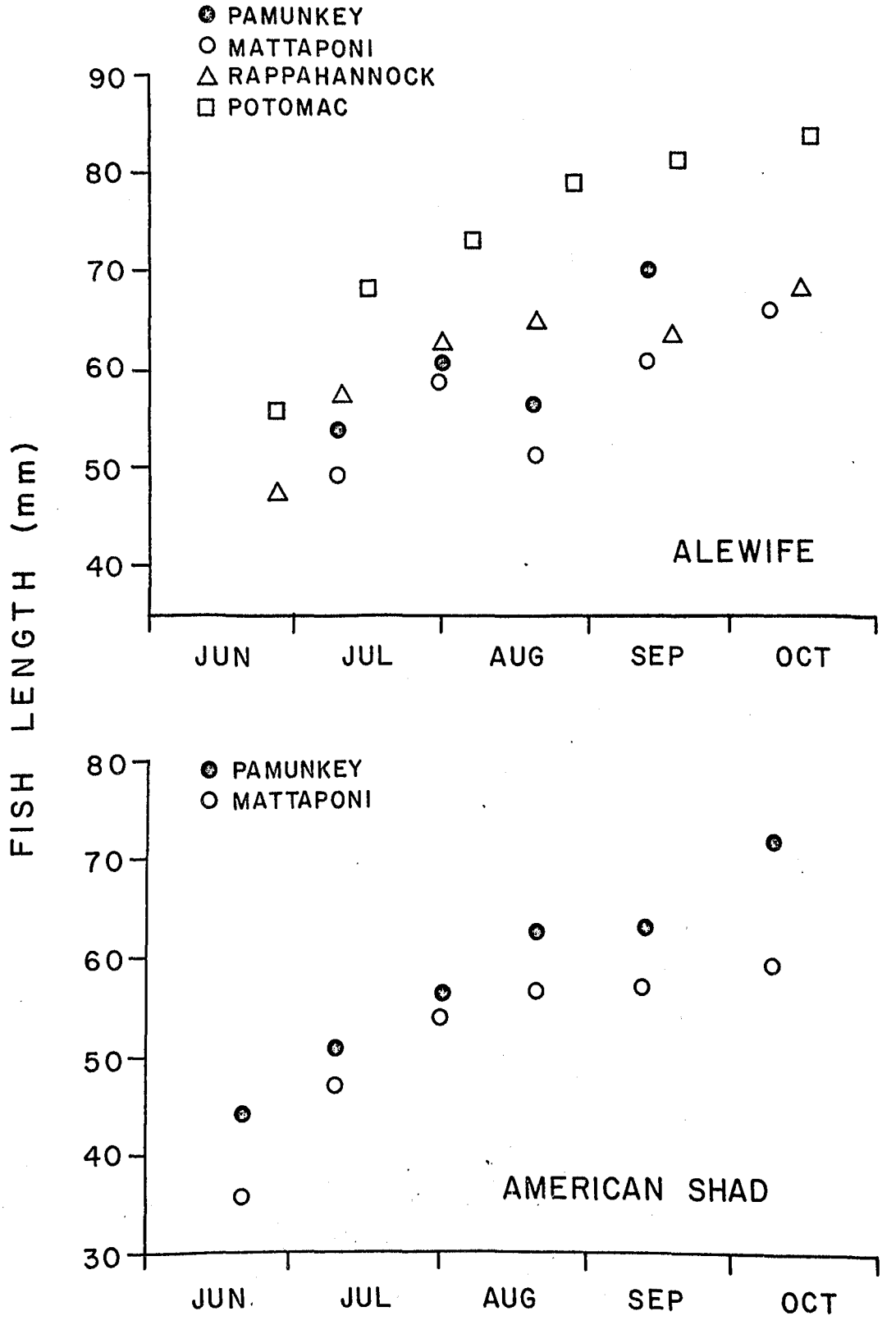

Figure 3.1. Growth curves for juvenile alewives and American shad in 1979.

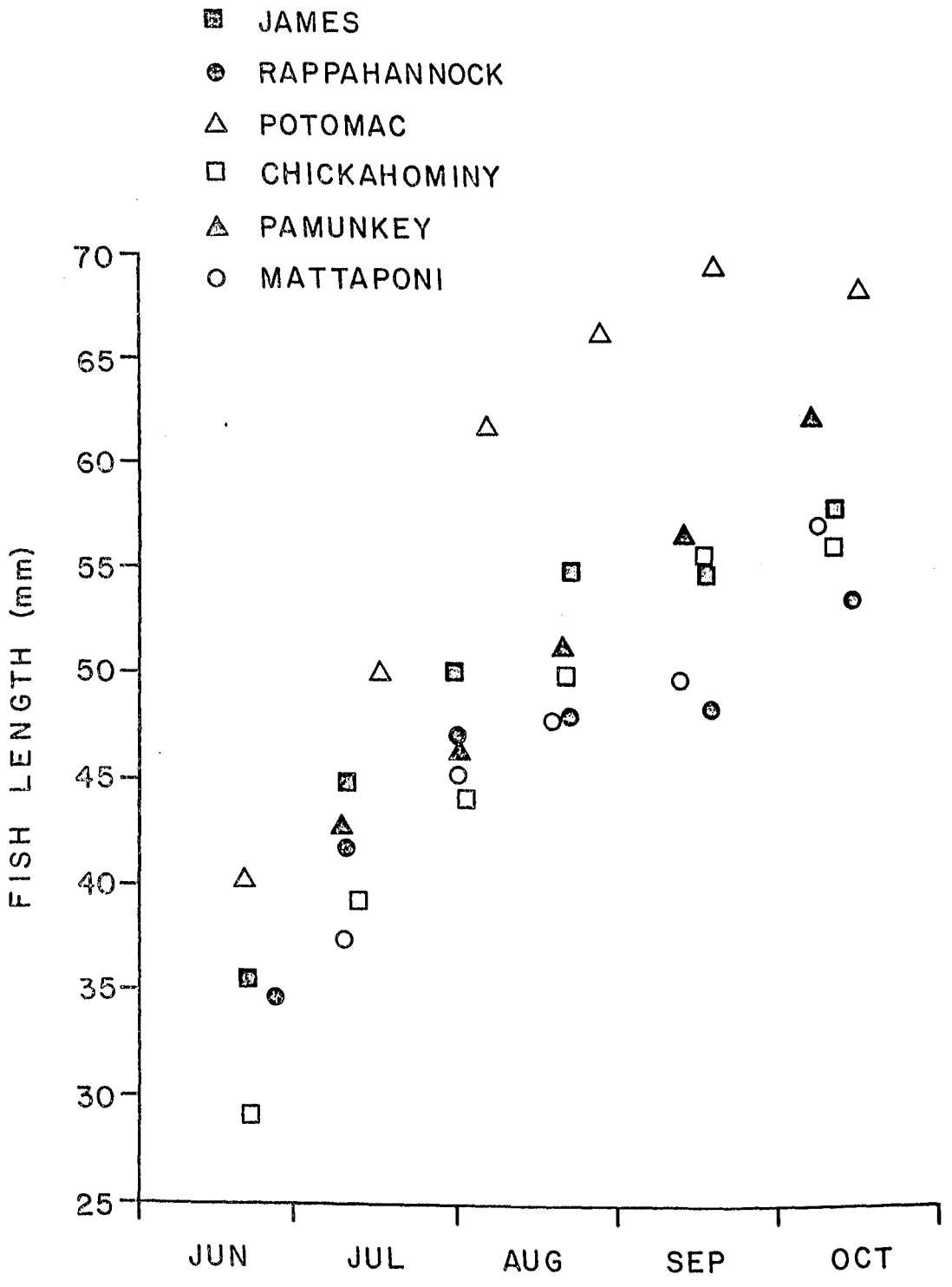

Figure 3.2. Growth curves for juvenile blueback herring in 1979.

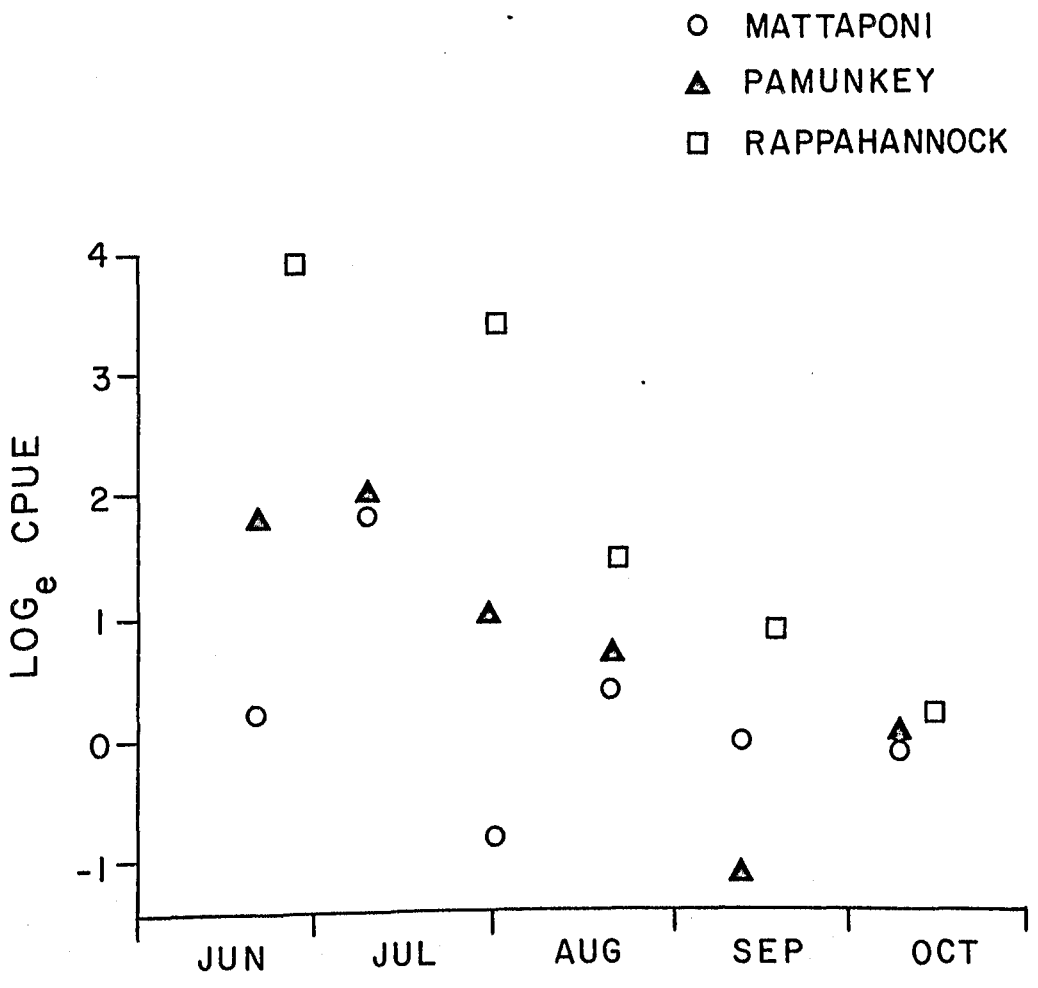

Figure 3.3. Catch curves for juvenile alewives in 1979.

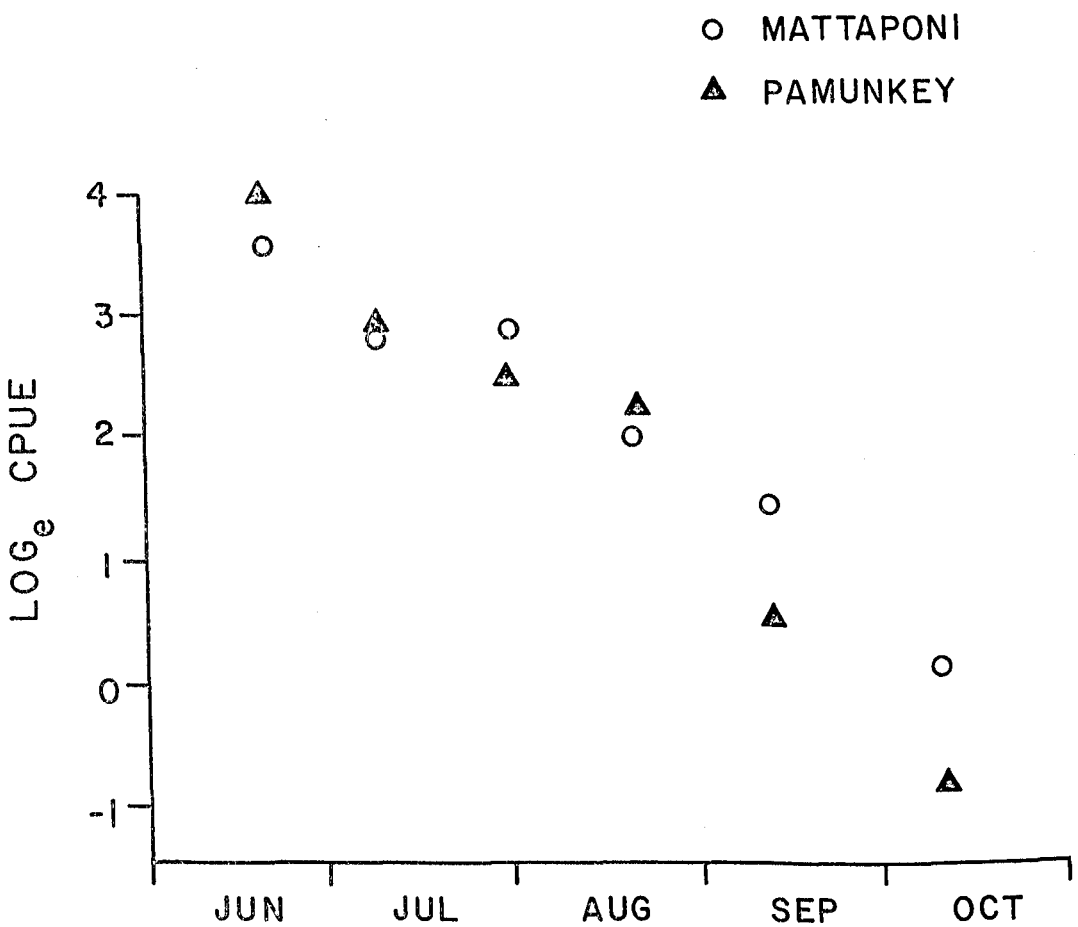

Figure 3.4. Catch curves for juvenile American shad in 1979.

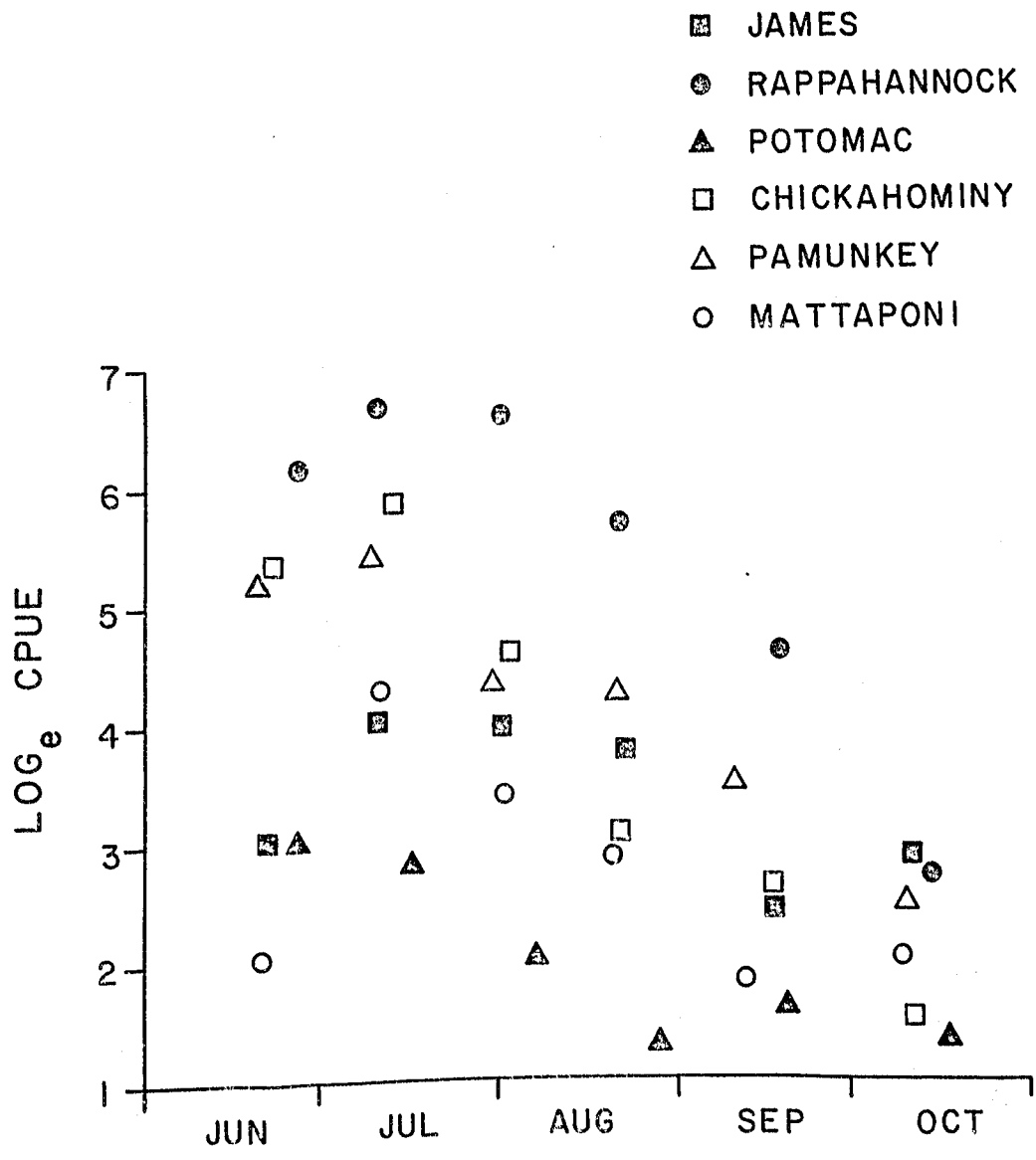

Figure 3.5. Catch curves for juvenile blueback herring in 1979.